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SPECIAL FEATURES

Honor French Scientist and Inventor

Selects Nominating Committee for 1921-22

Educational Program Receives Endorsement

Some Brinell Hardness Measurements on Small Specimens — *E. D. Campbell*

Repairing Tool Steel at the Mill — *A. W. F. Green*

Heat Treatment of Steel for Ordnance Purposes — *H. F. Leary*

Efficiency of Different Mixtures for Cyanide Hardening and the Role of Nitrogen in the Process — *Victor E. Hillman*

Fatigue of Metals Under Repeated Stress — *H. F. Moore and J. B. Kommers*

Reclaiming High Carbon Gears — *R. L. Dowdell*

Occurrence of Oxides and Nitrides in Boiler Tube Steel — *A. E. White and J. S. Vanick*

Carbonizing with Wood Charcoal — *H. Schagrin*

Automatic Compensation for Variations in Temperature of Cold Ends of Thermoelectric Pyrometers — *William H. Bristol*

Table of Contents, Page 27

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4600 Prospect Avenue

Announcement

Change of Location

The Alfred O. Blaich Co., manufacturers of "BLAICH MODERN CARBONIZER" and products used in the art of Heat Treating, announce their removal from Chicago to their new plant at 555 Beaufait Street, Detroit, Michigan.

Kindly address all communications accordingly to

ALFRED O. BLAICH CO.

555 Beaufait St.
Detroit, Mich.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. II Cleveland, January, 1922 No. 4

INDICATIONS BESPEAK BETTER BUSINESS FOR 1922

WITH the passing of 1921 an unsatisfactory year for business in general has been recorded in industrial history. As far as the iron and steel industry was concerned, at no time during the twelve months did business approach anything near a normal basis. The slump affected both raw materials and finished products in about the same degree. Production of pig iron fell to a historically low point due to an unusually severe curtailment of operations in June and July. Steel ingot output closely paralleled that of pig iron. The automobile industry which requires large tonnages of castings and many grades of steels has been producing on a greatly reduced plane. All this industrial inactivity has resulted in unemployment and idle equipment.

As unsatisfactory as 1921 may have been, present indications for 1922 bespeak of better business. In the first place, certain national conditions have been improved. Financial needs of the government have been pared sharply and through a still unsatisfactory but moderated tax law, taxes have been lessened both upon private individuals and industry. A suitable tariff law protecting American goods and manufacture is expected to be forthcoming early in the year. As a result of the recent limitation of armament conference, expenditures for naval expansion have been greatly reduced.

Industry once more released from burdensome taxation will be free to pursue its course on a normal basis and with its retrenched policies will be in excellent position to rebuild trade. Hope of reduced freight rates and transportation charges also spurs industrial activity. During the final months of 1921, pig iron and steel ingot production witnessed gradual improvement and an increasing number of inquiries indicated the closing of many orders in the first quarter of the new year. Although no spurt is expected, it is intimated in financial and industrial circles this year will see a gradual recovery to normal conditions.

NEW DEPARTMENT OFFERS INCREASED SERVICE

ANOTHER feature has been added to TRANSACTIONS, that of "The Question Box" which appears on page 346 of this issue. While this department is not new so far as affairs of the local chapters are concerned, it is new in this publication and has been inaugurated with the view of giving increased service to members of the Society. It will appear regularly as a department, its success depending upon the support which it receives. Members of the Society are urged to submit questions as they arise and those in a position to answer questions are requested to submit discussions. Many questions naturally must arise in every day shop practice to say nothing of problems which arise in experimental work in the laboratory. Thus questions

should be forthcoming in sufficient number to warrant the expansion of this department, thereby adding to its field of usefulness. To facilitate handling of "The Question Box," each question will be given a serial number, and members in sending in answers and discussions are requested to refer to these numbers, thus eliminating confusion and errors. In brief the purpose of this new department is to serve as a round table where practical questions may be asked and practical answers and discussions may be returned. Members of the Society are sincerely urged to make this their department, otherwise it must fail from lack of interest.

WILL HONOR INVENTOR OF THERMOCOUPLE

RECOGNITION for his achievements in advancing the heat treating and metallurgical professions to their present day standards is to be given Prof. Henry Le Chatelier by presenting to him on the fiftieth anniversary of his scientific career a suitably inscribed gold medal bearing his effigy. It is widely known, of course, that Professor Le Chatelier is the inventor of the platinum thermocouple, but in addition he has made numerous valuable contributions to science. If for no other accomplishment, the noted French scientist is deserving of proper recognition for development of the thermocouple. In the evolution and advancement of metallurgical operations, the thermocouple has become universal as an accurate means for measuring temperature and with its adoption former rule of thumb methods have become obsolete. The thermocouple with its highly developed registering device, the pyrometer, has had much to do with promoting both quality and quantity production. It is of fundamental importance.

For the purpose of expressing to Professor Le Chatelier the appreciation of the heat treating and metallurgical professions, a French committee has been organized to collect funds for striking and presenting the medal. In order that America may be represented in the movement, a subcommittee of prominent American metallurgists and scientists has been appointed to secure funds in this country. What this committee expects to accomplish and the methods to be used are outlined in detail on another page of this issue. As the date of presentation of the medal will take place in the near future, prompt response is desired. It is to be hoped that members of the American Society for Steel Treating will accept the opportunity for honoring Professor Le Chatelier for his work in advancing their profession.

SET DATE FOR WINTER MEETING

THE Winter Meeting of the Society, or New York sectional meeting, will be held in the Engineering Societies building, 29 West Thirty-ninth street, New York, on Friday, March 3. As yet the program is not completely arranged, however, several technical papers have been secured. A few of them will appear in the February issue of TRANSACTIONS while the balance will be placed in preprint form.

TRANSACTIONS INDEX IS READY

AN INDEX for Vol. I of TRANSACTIONS has been prepared and is now ready for distribution to readers. A copy may be obtained upon request to the National Secretary, 4600 Prospect avenue, Cleveland. It contains the names of 84 authors. For convenience in finding articles, the cross index method has been used, some 300 subjects being listed. To facilitate binding, the index is printed in pamphlet form and the same page size as TRANSACTIONS.

WILL HONOR FRENCH SCIENTIST AND INVENTOR

A MOVEMENT has been started to honor Prof. Henry Le Chatelier, prominent French scientist and inventor by presenting to him a medal bearing his effigy. To assist in this movement, an American subcommittee has been selected to represent the metallurgists, chemists and scientists of the United States, the chairman being Prof. Albert Sauveur. The work of Professor Le Chatelier is of special significance to all heat treaters for to this man must be given the credit for inventing the platinum thermocouple. Members of the Society are given the opportunity to contribute through the blank which is shown below. The committee desires to have the money in hand at the earliest possible moment. Following is a self explanatory letter sent out by the American subcommittee:

To the friends and admirers of Prof. Henry Le Chatelier and to those who have profited by his inventions and his writings.

A number of colleagues, friends and students of Prof. Henry Le Chatelier desire to commemorate the fiftieth anniversary of his scientific career by the casting of a medal bearing his effigy, to be presented to him. An American subcommittee has been organized in order that American metallurgists, chemists and scientists may participate in this testimony to one to whom we owe so much.

It is not desired to send to the French committee from the United States funds in excess of one thousand dollars, although the sum subscribed should be large enough to cover the printing, mailing and other expenses of the committee.

It is believed that those who recognize the great value to science and to the metallurgical and chemical industries of the contributions of Prof. Henry Le Chatelier will be glad of this opportunity to associate themselves with this mark of esteem and admiration. Subscriptions of one to five dollars will be welcome by the committee.

Contributions should be addressed to Bradley Stoughton, 29 West 39th Street, New York.

If you desire to subscribe, kindly sign the enclosed slip, but do not indicate on it the sum subscribed. These slips will be forwarded to Professor Le Chatelier, and the committee hopes that it will be able to secure at least one thousand of them.

I desire to associate myself with the presentation of a medal to Professor Henry Le Chatelier, member of the Institute of France, as a token of admiration for his work, and of gratitude for the benefits it has bestowed on the scientific and industrial world.

Name.....

Address.....

Position.....

SELECTS NOMINATING COMMITTEE FOR 1921-1922

PRESIDENT F. P. GILLIGAN, of the American Society for Steel Treating, has announced the appointment of the Nominating Committee for the selection of national officers for the year 1921-1922.

The personnel of this committee is as follows:

Chairman, D. W. McDowell, chief inspector, Jones & Laughlin Steel Co., Pittsburgh, Pa., and Secretary of the Pittsburgh Chapter.

The members of this committee are:

H. C. Goodwill, superintendent of dies, R. Wallace & Sons Mfg. Co., Wallingford, Conn., and Chairman of the New Haven Chapter.

W. J. Priestley, superintendent of hot metal department, United States Naval Ordnance Plant, South Charleston, W. Va., and Chairman of the Charleston Chapter.

C. W. Schumann, mechanical engineer, Miehle Printing Press & Mfg. Co., Chicago, Ill., and ex-secretary of the Chicago Chapter.

C. S. Moody, metallurgical engineer, Minneapolis Steel & Machinery Co., Minneapolis, Minn., and ex-chairman of the Northwest Chapter.

This committee will announce its selection of candidates for national officers in June. These new officers will be elected by mail ballot sent to the members of the Society and will assume their offices during the 1922 National Convention at Detroit, Sept. 25 to 30.

Voting members of the Society are requested to recommend to the committee the names of eligible persons for the elective offices.

EDUCATIONAL PROGRAM RECEIVES ENDORSEMENT

CONSIDERABLE attention has been attracted to the educational program which various chapters of the American Society for Steel Treating have initiated during the past few months. So far as its educational work is concerned, the Society today probably is leading the field. This policy has been endorsed by the *Iron Age* which in its Dec. 1 issue speaks editorially as follows:

"A unique development in the work of the American Society for Steel Treating had its inception last year in one of the New England districts where certain chapters started an educational program at their monthly meetings. This year the movement has so far expanded that the society may be said to take the lead in active educational work among its members. A conspicuous example is the Philadelphia chapter, which has organized an evening course in metallurgy and heat treatment at Temple University. In the New York chapter a series of monthly meetings has been arranged, the program for which contemplates a progressive course in steel metallurgy and heat treatment. Each month an authority in a particular line gives the chief lecture, which is followed by questions and discussions. Brief abstracts are given also of the principal articles on metallurgical subjects in the technical press. Other local chapters are adopting similar plans. Fostered by the national board of directors and by visits of the national president to local chapters, the departure promises greatly increased interest in the work of this enterprising society."

SOME BRINELL HARDNESS MEASUREMENTS ON SMALL SPECIMENS

By E. D. Campbell

THE value of knowing the Brinell hardness number of steel has been recognized for so many years that this method of testing has become almost universal. For the harder class of metals, such as steel, a standard condition of testing, using a 10-millimeter ball with a load of 3000 kilograms has been adopted generally, while for soft metals the same sized ball under a load of 500 kilograms is used. To insure accuracy of results when working under standard conditions, the width of the test specimen should not be much, if any, less than twice the diameter of the ball, nor the thickness much less than the diameter. The scleroscope has been found satisfactory for testing many small specimens and thin plates or sheets. During the war some new forms of Brinell machines, adapted for use with small balls only and a very light load, intended for testing thin sheet brass, such as cartridge cases, were perfected. Special devices were required for measuring the diameters of the impressions made with these small balls and new tables had to be computed to convert the values obtained into Brinell hardness numbers.

In the course of the researches on the constitution of steel, which have been carried on in this laboratory during the past 30 years, it has been found during the last 6 or 7 years that small bars about 6 millimeters square and 15 centimeters long are better adapted to the facilities available, both for heat treatment and measurement of such properties as specific resistance, thermal resistivity, thermoelectromotive potential, etc., than any other size tried. Six or seven years ago a standard Alpha Brinell machine was imported and has been in regular use whenever specimens were large enough to be tested under standard conditions.

The object of the present paper is to describe an attachment for the standard Alpha Brinell machine, which attachment has been in use in this laboratory for the past two or three years and enables hardness measurements to be made on small bars with almost as much ease and accuracy as can be done on larger specimens, working under standard conditions. In Fig. 1 are shown, in addition to the large regular balance, corresponding to a pressure of 500 kilograms on the ball, the light balance giving 95 kilograms pressure; two weights giving an additional 21 kilograms and three holders for balls of 10, 5, and 2-millimeters diameter.

The principle involved in working out the light balance was that if a small ball—2-millimeters being adopted—were pressed into a smooth surface of given hardness and the image of the impression observed when a 16-millimeter objective is substituted for the 48-millimeter regularly supplied with a Brinell microscope, there must be some pressure which applied to the 2-millimeter ball would give an impression which viewed through the 16-millimeter objective would appear the same size as an impression made with a 10-millimeter ball under 3000 kilograms load on the same surface, but observed through the 48-millimeter objective.

An approximate calculation of the weight necessary for a light balance, was computed from the following data. The large balance, equivalent to

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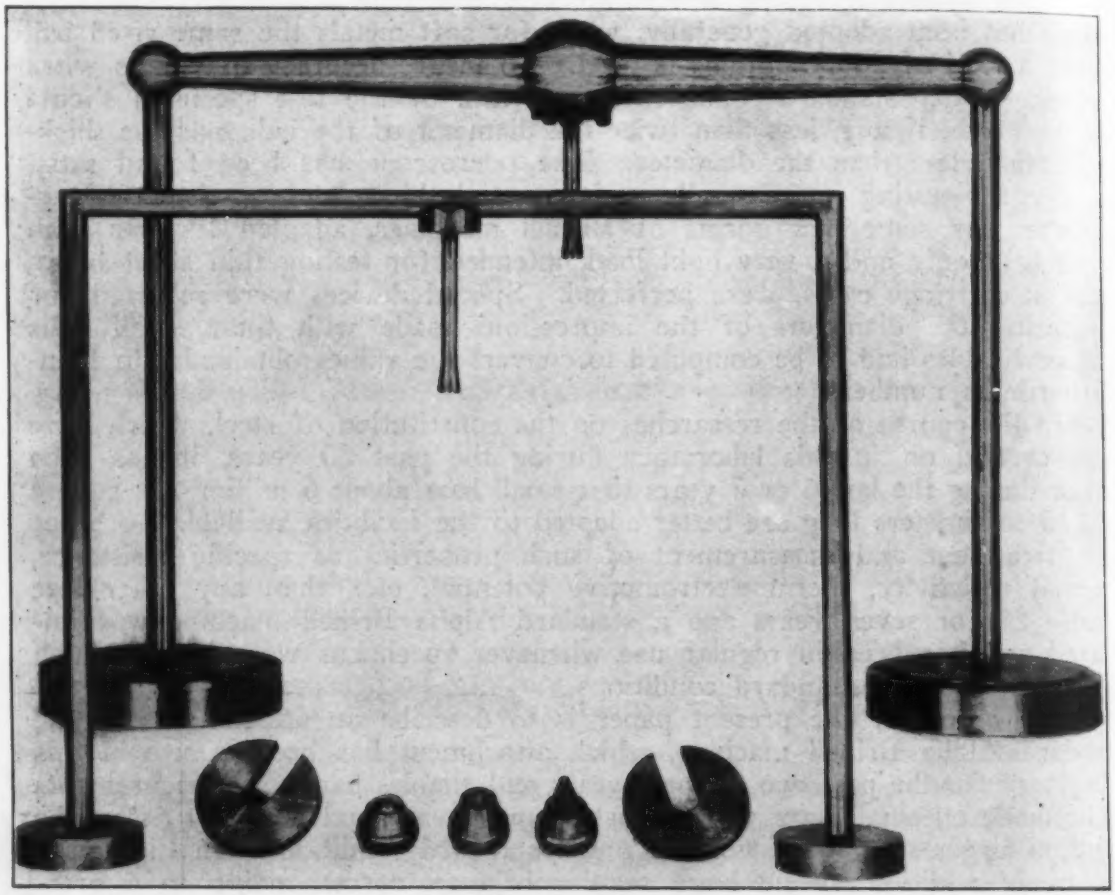
A paper presented by title at the Indianapolis Convention. The author, E. D. Campbell, is professor of chemistry, University of Michigan, Ann Arbor, Mich., and an honorary member of the American Society for Steel Treating.

500 kilograms, weighed 3944 grams or a little less than 7.9 grams for each kilogram pressure. When the 16-millimeter objective was substituted for the 48-millimeter, the magnification was increased 5.75 times. The pressure, therefore, which it would be necessary to apply to a 2-millimeter ball, would be approximately 3000 $(5.75)^2$ or very nearly 91 kilograms. In order to allow for possible friction of the piston, etc., a balance was constructed from light brass tubing, the whole weighing a little over 800 grams or equivalent



LARGE REGULAR BALANCE FOR ALPHA BRINELL MACHINE, LIGHT BALANCE GIVING 95 KILOGRAMS PRESSURE, TWO WEIGHTS GIVING ADDITIONAL 21 KILOGRAMS AND THREE HOLDERS FOR 10, 5 AND 2-MILLIMETER BALLS

to something over 100 kilograms. A piece of steel of uniform hardness and large enough to use under standard conditions was then carefully polished and duplicate impressions made with a 10-millimeter ball under 3000 kilograms pressure. The light balance was then submitted for the regular one and the 2-millimeter ball substituted for the 10-millimeter. An impression made with the 2-millimeter ball with the light balance was then observed through the 16-millimeter objective. The impression appeared, as was expected, a little larger than the standard observed through the 48-millimeter objective. The light balance was then removed, the weight dressed down a little, and the balance again tested as before. The light balance was thus experimentally calibrated until finally, when the weight had been reduced to an equivalent of 95 kilograms, the image obtained with the 2-

millimeter ball under 95 kilograms observed through 16-millimeter objective exactly coincided with that obtained with the 10-millimeter ball under standard conditions.

Comparisons were then made through a wide range of hardnesses, from that of ingot iron to freshly hardened hyper-eutectoid steels, the results obtained agreeing equally well through the whole range. In order to obtain close agreement, it would of course be necessary that each instrument be calibrated individually in accordance with the relative magnifying power of the objectives used. If the instrument is thus calibrated, the tables of hardness numbers computed for the 10-millimeter ball under 3000 kilograms may be used equally well when the hardness is measured with a 2-millimeter ball under 95 kilograms, but the image observed with the 16-millimeter objective.

In order to adapt the instrument to the measurement of soft metals such as are ordinarily measured with the 10-millimeter ball and 500 kilograms pressure, the following changes were made. A carefully polished surface of pure annealed copper was used in calibrating. Duplicate impressions were made on this with a 10-millimeter ball and 500 kilograms and observed in the usual manner. A 5-millimeter ball was then substituted for the 10-millimeter and an impression made with the 95 kilogram balance. When this latter impression was observed through a 32-millimeter objective, which would increase the magnification 2.20 times as compared with a 48-millimeter objective, it appeared somewhat too small. Ordinary weights were then added to the balance, new impressions made and observed through the 32-millimeter objective until it was found that the addition of weights equivalent to 21 kilograms would give an impression which when observed through a 32-millimeter objective, exactly coincided with that from a 10-millimeter ball under 500 kilograms and measured in the usual way. By using a 5-millimeter ball under 116 kilograms pressure and observing through a 32-millimeter objective, the same hardness tables, giving values for a 10-millimeter ball under 500 kilograms pressure, may be used.

To obtain the most satisfactory results when using a 2-millimeter ball with the light balance, a number of conditions should be observed. By rubbing a little heavy grease in the hemispherical depression of the holder and then pressing the ball in, the latter will have no tendency to fall out when in use. Magnetizing the holder causes the ball to leave the depression and seek the edge of the holder. The surface to be tested must be polished almost the same as for metallographic work, although some very fine scratches are often useful in detecting the outline of the depression, since the pressure of the ball produces a perfect polish in the depression itself. When the surface to be tested has been polished, it should be rubbed over with a slightly oily cloth, to lessen the friction between the ball and the surface of the metal being tested. When making an impression, the pumping up to the point where the balance rises should be done slowly and carefully to avoid any temporary excess of pressure, and when the pressure is up to that indicated by the balance, it should be held at this point at least 1½ minutes to insure equilibrium. On account of the small size of the impressions and the use of a 16-millimeter objective, it is necessary to use a fine adjustment in order to focus. For this purpose the tube of the Brinell microscope may be placed in an ordinary microscope stand and a mechanical stage may be used for moving the specimen until the impression is in position for focusing and reading the diameter. Strong daylight gives decidedly

the most satisfactory illumination, but when this is not practicable oblique illumination from two lamps, one on each side of the specimen, may be used.

About a year ago, in an article on "Notes as to Rates of Reaction in Certain Steels at 930 Degrees Cent.," (Journal Iron and Steel Institute, 1920, No. II, page 281), the author submitted experimental evidence which showed that when bars 6 millimeters square and 15 centimeters long were quenched

TABLE I

Composition of Steels and Quenching Temperatures

Steel No.	Quenching temperature degrees Cent.	Composition weight, per cent — Carbon	Mang.	Phos.	Sulphur	Silicon	Nickel	Chrom.	Tungs.	Iron
1*	938	.076	.122	.03	.017	3.65	...	...	...	96.10
2	897	.133	11.57	.055	.026	.25	...	...	...	88.00
3*	938	.036	.677	.038	.020	.231	2.80	...	...	96.2
4*	940	.027	.405	.013	.018	.162	4.48	...	...	94.9
5*	930	.035	.38	.007	.003	.45	...	1.40	...	97.7
6	897	.026	.32	.018	.006	.12	...	.24	5.04	94.2
7*	930	.23	.27	.02	trace	.88	...	14.32	...	84.3
8	840	.68	.37	.015	...	.29	...	.32	5.50	92.8
9	906	.35	.08	.009	.024	.018	...	...	...	99.3
10	910	.76	.22	.016	.041	.169	...	...	...	98.8
11	910	1.39	.27	.021	.015	.16	...	...	...	98.1

*Indicates bars tempered 110 degrees Cent, iron determined by difference.

in cold water, the rate at which the section first entering the water passed through the critical range must have been slower than at which the last section, No. 15 passed through the same temperature range, since there was enough difference in the concentration of the carbides remaining in solution to produce an easily measurable difference in thermoelectromotive potential at the two ends of the bar.

Since Brinell hardness is due largely to a state of strain, the amount of which strain is influenced by both the carbide concentration at the instant of quenching and the rate at which the metal passes through the critical range, it was thought that perhaps some further light might be thrown on this subject by measuring the hardness at both ends of a number of steels with widely varying carbide concentrations. Eleven steels, in the form of bars 6 millimeters square and 15 centimeters long, were selected for the work. The first six were steels which had been decarburized with hydrogen according to a method described in an article by the author on "The Decarburization of Steel with Hydrogen," (Journal Iron and Steel Institute, 1919, No. II, page 407). The seventh was a high chromium stainless steel; the eighth, a special magnet steel; while the last three were straight carbon steels, differing widely in carbide concentration. The compositions of these steels together with temperatures of quenching are shown in Table I.

After the heat treatment, the ends of the small bars were ground carefully and polished. Two heavy steel blocks, which had been used as a mold, served as a holder for the small bars while the Brinell impressions were being made. As in the paper on "The Rates of Reactions in Certain Steels at 930 Degrees Cent.," these bars should be considered as being made up of fifteen sections, each 1 centimeter long, Section 1 being the end of the bar first touching the water and Section 15 the last. The total time required for complete immersion of the bar, from the time Section 1 touched, did

not exceed probably 1/10 of a second, and the time required to cool from the quenching temperature to the time no color was visible, was from 4/5 of a second to 1 second. The total time from the time of quenching until the bars were down to bath temperature, was from 5 to 6 seconds. The results of the Brinell measurements at the two ends of the bars, and the average hardness are given in Table II.

A study of the data in Table II shows that in the strongly hypoeutectoid steels, Nos. 3. 4, 5, 6, 7, and 9, whether nickel, chrome, or straight carbon steels, the rate of transformation of the gamma to the alpha form is so rapid that the difference in the rate of cooling between Section 1 and Section 15 is enough to make a measurable difference in the amount of metal trapped in the transition state, hence in the degree of strain set up. This is indicated by the greater hardness of Section 15 as compared with Section 1.

As has been known for many years, when manganese is atomically substituted for iron, it tends to retain the metal in the gamma or nonmagnetic state. In steel No. 2, although the carbide concentration is quite low, the effect of the high manganese in suppressing the rate of transportation of the gamma to the alpha state, is sufficient so that the difference in the rate

Table II

Brinell Measurements at Opposite Ends of Bars

Steel No.	Carbon per cent	Quenching temperature degrees Cent.	——Brinell hardness number—— Section 1	Section 15	Average
1	.076	938	228	187	207
2	.133	897	364	364	364
3	.036	938	286	302	294
4	.027	940	202	228	215
5	.035	930	183	207	195
6	.026	897	156	241	198
7	.23	930	311	364	337
8	.68	840	713	713	713
9	.35	906	418	512	465
10	.76	910	600	600	600
11	1.39	910	782	782	782

of cooling of Section 1 compared with Section 15 is not noticeable, the bar having the same degree of hardness at both ends.

Since the effect of increasing the carbide concentration is also to suppress the rate at which the gamma iron transforms into the alpha condition, by this time the carbide concentration approaches the eutectoid point, as in samples 8, 10 and 11, the effect of this retardation is also great enough so that the difference in rate of cooling between Sections 1 and 15 is not noticeable and the bars have the same hardness at both ends.

These hardness measurements therefore seem to confirm the conclusions concerning rates of reactions in steels at high temperatures, drawn from the previous studies on thermoelectromotive potential.

PREPARING TOOL STEEL AT THE MILL

By A. W. F. Green

MANUFACTURE of tool steel embodies a number of operations starting with the melting and continuing through the blooming, pressing, hammering, rolling and annealing processes. The quality of the product is determined by the amount of care exercised in the selection of raw materials used in the melting process, and all subsequent operations.

The chief considerations of this article are the effects of proper finishing temperatures in the hammer shop and rolling mill on the steel, and the normalizing and annealing of the product. It is not possible in this short discussion to go into detail concerning the other operations which have been outlined. Discussion is limited to straight carbon and one or two alloy steels exclusive of high speed steel.

Hammering of tool steel may be divided into two separate operations, namely, cogging down, and finishing to a size. It is often the case that the two processes are completed with but one heating of the material. Cogging down consists in heating an ingot, bloom or billet to a suitable temperature, from 1800 to 2100 degrees Fahr., depending upon the temperature at which hammering is to be stopped, and breaking it down into multiples of a size which may be more easily handled in the rolling mill or under smaller hammers. Cogging down usually is accomplished with hard blows of the hammer, the finishing temperature being generally in excess of the Ar range of the material, 1400 to 1600 degrees Fahr. After cogging down to the desired size and shape, the pieces are allowed to cool, in the air, or in lime, ashes, etc., so that normalizing or partial annealing are accomplished without placing the material in special furnaces for that purpose.

Finishing to a size is done by reheating the cogged down pieces to a suitable temperature, 1800 to 2000 degrees Fahr., and then working them down to the desired size and shape. The blows at first are delivered hard, and as the material approaches the size and shape needed and also becomes colder, are increased in speed and made lighter so that the steel will not be ruptured and will be put into good condition structurally. "The colder the material is finished, the closer to the exact size it can be made, because it has less shrinkage to undergo; but it will be harder, less ductile and stronger."[2] Slow cooling in lime, ashes, etc., is sometimes done so that a certain amount of annealing or normalizing may take place.

Although it is certain that normalizing or annealing does take place to some extent when hammering is followed by air cooling from a temperature at or above the critical Ar range of the steel, it is often the case that but relatively small areas are benefited. There are several reasons why this is so. "The principle of the hammer is that of an almost instantaneous application of pressure applied to a relatively small area. This makes hammering a slow process of reduction but results in a more uniform and better working of the crystals on the surface at least, which is one of the chief reasons for the superiority of hammered over rolled material".[2] Thus if hammering is stopped at a temperature from which normalizing or annealing is possible, it is evident that the structural conditions of the ex-

1. "Metallurgy of Iron and Steel," by Stoughton.
2. "The Making, Shaping and Treating of Steel," by Camp.

A paper presented at the Indianapolis Convention. The author, A. W. F. Green, is chief of laboratory, John Illingworth Steel Co., Philadelphia.

terior and the interior of the material are different. This is illustrated by photomicrographs in Figs. 3 and 4, which were taken from a steel containing 1.20 per cent carbon and 1.25 per cent tungsten after being hammered. Fig. 3 represents a section of the material taken along the surface, while Fig. 4 shows a section of the center of the same bar. It will be noticed that in the latter section, evidence remains of the original ingot structure in the needles of free cementite within the grain boundaries and which are entirely in solution in the grains making up the exterior portion of the material. Thus, it is evident that to secure the best effects of normalizing or annealing, the steel should be given a separate treatment than that which may be given by regulating the cooling from the finishing temperature.

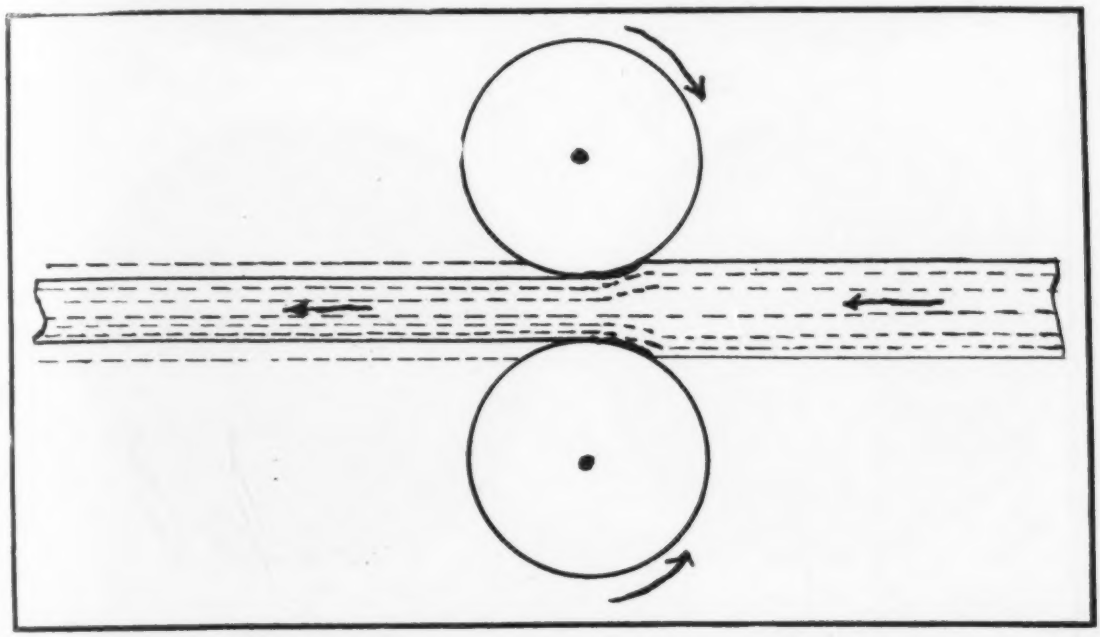


Fig. 1—Diagram illustrating the action of the rolling mill on material passing through. Drawing taken from Camp.

The chief effects of hammering, therefore, are gained by control of the heating and finishing temperatures of the steel as related to time, mass, surface, and the size of the hammer. Care must be exercised at all times to keep the furnaces used free from cutting flames and severely oxidizing atmospheres. To illustrate the effects of improper furnace conditions on structure, reference is made to Figs. 5, 6, 7 and 8. In Fig. 5 is shown the cast structure of a steel containing 0.50 per cent carbon, and 1.50 per cent nickel. This steel when properly heated for hammering and finishing correctly, has a structure as shown in Fig. 6. When undue blast and intense flame is used for quick heating, and the steel is improperly cared for, structures such as shown in Figs. 8 and 6 result. Fig. 7 also shows some of the effects of the severe decarburization which may take place.

Rolling of tool steel also may be divided into two operations, namely, cogging down, and finishing. However, because of the speed with which these operations are carried on and usually without the necessity for two heatings, it is difficult to draw a sharp line between them.

"The process of shaping steel by rolling consists essentially of passing the material between two rolls revolving at the same peripheral speed and in opposite directions, that is clockwise and counter-clockwise, and so spaced

that the distance between them is somewhat less than the height of the section entering them."[2] Various forces are, therefore, brought to bear upon the metal entering the rolls and are demonstrated somewhat by the drawing shown in Fig. 1, after Camp. "The exact crystalline action that takes place under mechanical treatment is not known. In the case of rolling, Professor Howe has tentatively assumed the conditions graphically shown in Fig. 2 in which the abscissa line represents the size of grain at the different temperatures. At 2550 degrees Fahr. the grain size is represented by the hori-

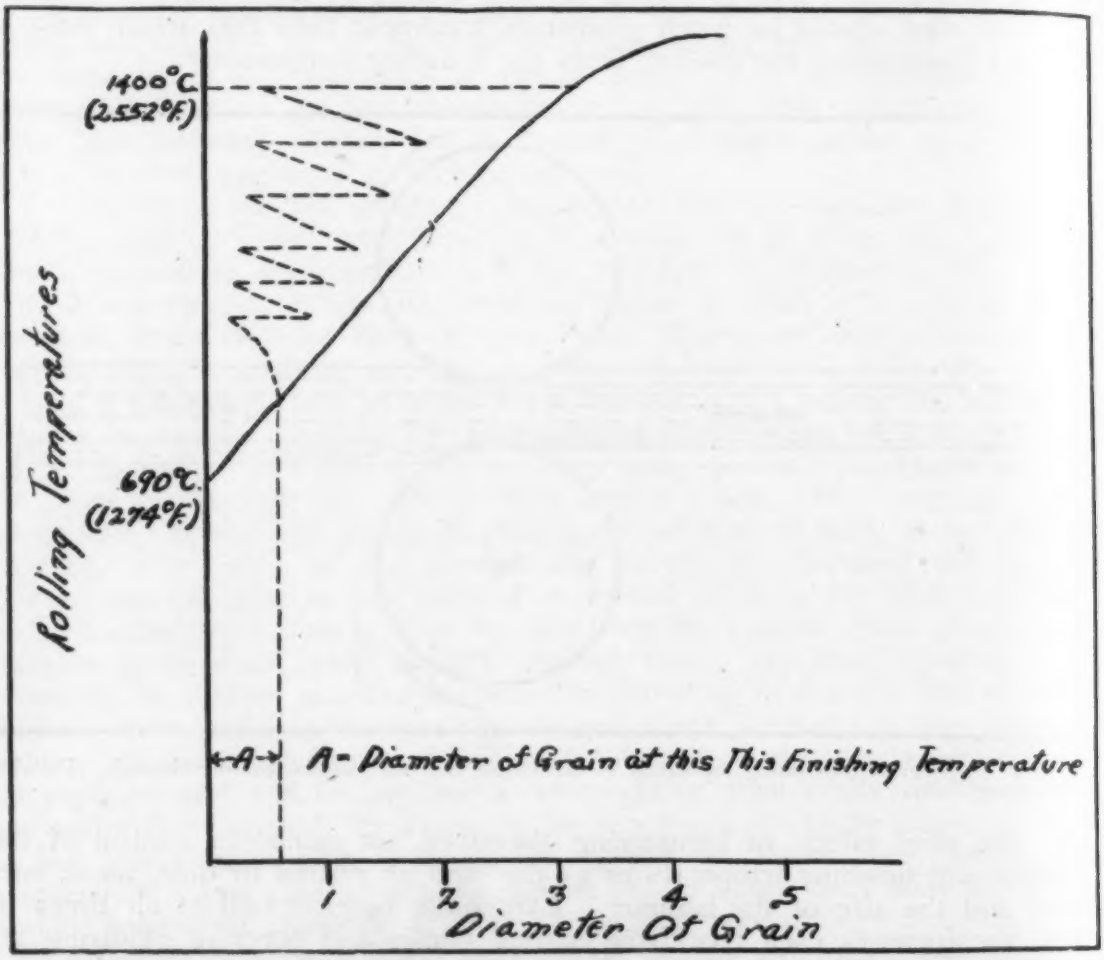


Fig. 2—Graphical representation of grain size at the different temperatures as steel receives passes through the rolling mill. Reproduced from Howe's "Iron, Steel and Other Alloys."

zontal dotted line from vertical axis. On the first passage through the rolls the grains are crushed to a very small size, but on emerging again they grow rapidly. Meanwhile, however, the metal has been cooled, and this fact, as well as the inability of the grains to grow constantly, causes the new size of grain to be smaller than before. Therefore, each passage through the rolls renders the crystals smaller in size, the final size depending upon the temperatures and the amount of reduction in the last pass."[2] It is quite evident that to place rolled steel in the best condition for future use, rolling must be followed by normalizing or annealing or both of these treatments.

The temperatures to which steel is heated for rolling are generally in excess of those employed for hammering, namely 2000 to 2400 degrees Fahr. and consequently because of the process it is a great deal

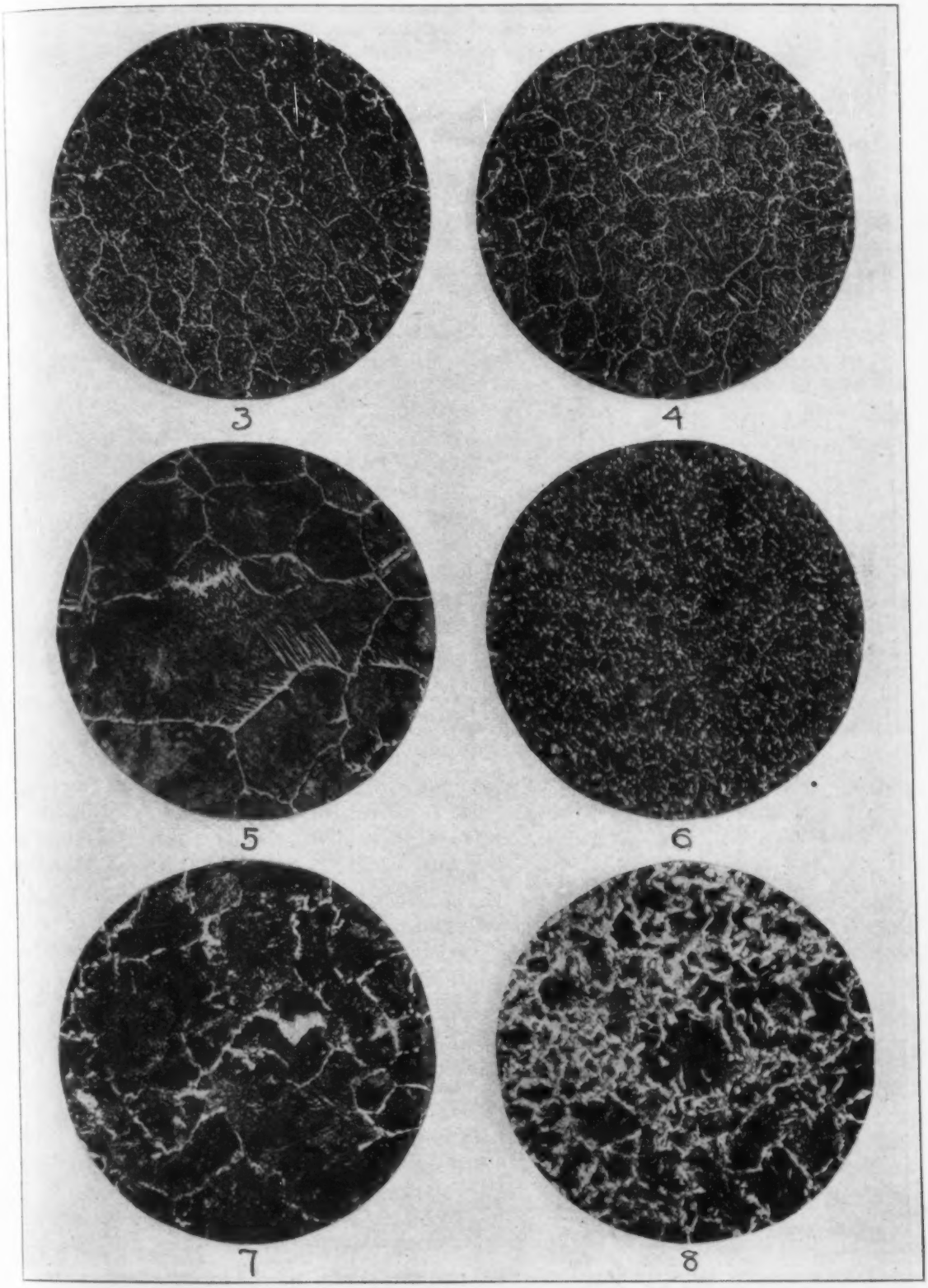


Fig. 3—Structure on surface of 1.20 per cent carbon, 1.25 per cent tungsten forged bar. Etched with 10 per cent nitric acid and X 120. Fig. 4—Structure in center of same bar shown in Fig. 3. Etched with 10 per cent nitric acid and X 120. Fig. 5—Cast structure of 0.50 per cent carbon, 1.50 per cent nickel steel. Etched with picric acid and X 120. Fig. 6—Structure of correctly hammered bar of same steel shown in Fig. 5. Etched with picric acid and X 120. Fig. 7—Structure of same steel as Fig. 5 improperly heated for hammering. Etched with picric acid and X 120. Fig. 8—Structure of same steel as Fig. 5 improperly heated and showing excessive decarburization. Hammered structure. Etched with picric acid and X 120.

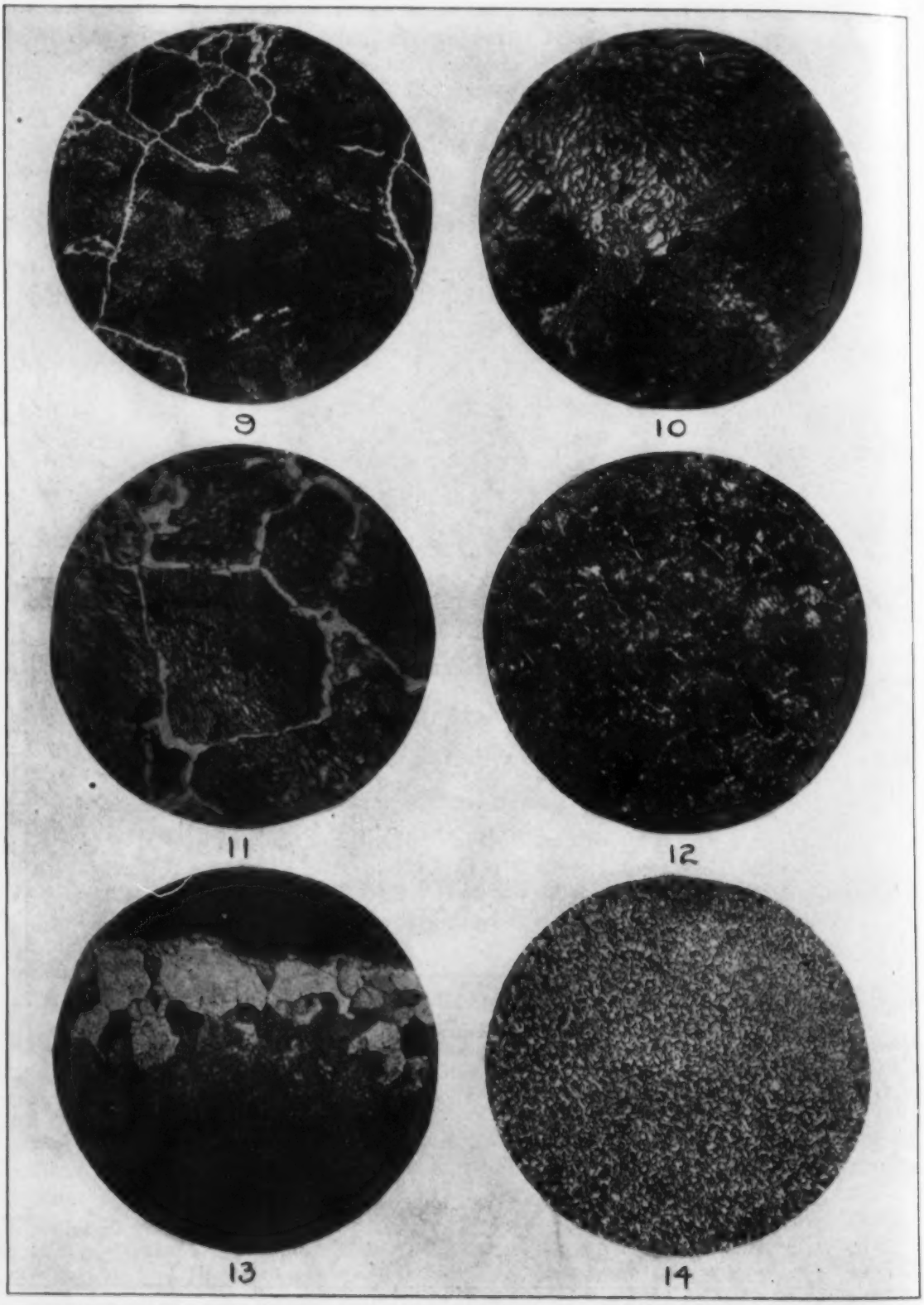


Fig. 9—Structure of 1.10 per cent carbon tool steel due to severe overheating in mill furnace. Etched with 10 per cent nitric acid and X 120. Fig. 10—Structure of 0.80-0.90 per cent carbon tool steel heated too high for work to be done in rolling mill. Etched with 10 per cent nitric acid and X 500. Fig. 11—Structure of 1.05 per cent carbon tool steel which has been heated too high in rolling mill furnace. Etched with 10 per cent nitric acid and X 500. Fig. 12—Structure of 1.05 per cent carbon tool steel heated 300 degrees Fahr. less than that shown in Fig. 11 and then rolled. Etched in 10 per cent nitric acid and X 120. Fig. 13—Structure of 0.80-0.90 per cent carbon tool steel showing excessive decarburization due to improper heating in mill furnace. Etched with picric acid and X 120. Fig. 14—Structure of 1.10 per cent carbon tool steel seriously decarburized in rolling mill furnace. Etched with 10 per cent nitric acid and X 120.

harder to control the finishing temperatures, or the temperatures at which rolling is stopped. These temperatures are dependent upon the kind of material being rolled, the size of the ingot or billet, the size and speed of the mill, and the number of passes employed in reducing the steel to the desired shape and size. A good illustration of this is shown in the rolling of two billets four inches square and weighing 160 pounds each. One contains 1.10 per cent carbon and the other 0.10 per cent carbon. Both are rolled to a 1-inch round section with eight passes in the mills. The temperature for rolling the first billet will approximate 2000 degrees Fahr., while the second or low carbon billet will be rolled from a temperature of about 2400 degrees Fahr.

Efforts are being made to obtain better control of heating temperatures for rolling mill work by the use of continuous billet heating furnaces in which furnace design and temperature control apparatus play an important part. It is necessary that the heater on a rolling mill furnace be an experienced and trustworthy man. His experience serves him in that he is able to give steels of varying chemical content the correct heating for the work to be given it in the mill. The effects of improper heating are shown to some extent in the photomicrographs of Figs. 9, 10 and 11. Fig. 9 represents the finished structure of a steel which was to have been used for making threading dies, containing 1.10 per cent carbon. Investigation showed that the steel had been placed in the furnace in such a way that it was exposed to a very hot flame, and after firing up the furnace the heater decided to go on a strike which lasted for three hours, and resulted chiefly in the ruination of the steel in the furnace. Fig. 10 shows the structure of an 0.80-0.90 per cent carbon tool steel which had been heated too high for the work to be done—the finished size was over 1½ inches in diameter—thus being finished at too high a temperature. Fig. 11 shows a steel containing 1.05 per cent carbon which had also been heated too high. Fig. 12 is the photomicrograph of a steel containing 1.05 per cent carbon which had been heated 300 degrees Fahr. less than that shown in Fig. 11 and finished at the correct temperature.

However, there is another serious defect which results from improper heating in the rolling mill furnace, and that is decarburization. Fig. 13 shows the decarburization occurring in 0.80 to 0.90 per cent carbon tool steel which has been exposed to a cutting flame and in a severely reducing atmosphere. Fig. 14 shows the same condition, but the effect is much more serious in that the carbon has been extracted to a greater depth by long heating in the rolling mill furnace under adverse conditions. Fig. 15 represents the decarburized structure of sheet steel used in the manufacture of knife blades, the effect being so serious that the steel had to be pickled in order that the oxide or scale would be removed from the decarburized surface, so that when the steel was reheated the new oxide would be formed of a good portion of the free iron of the low carbon area. This scale peeled off during finishing in the mill.

Figs. 16, 17, 18 and 19 represent a series showing the make-up of steel as it enters the rolling mill furnace and some of the structures subsequently produced. Fig. 16 shows the cast structure and Fig. 17 the structure of the steel as it comes from the cogging down rolls where it receives three passes in being reduced from a 4-inch square to 1½-inch square. Fig. 18 shows the finished structure of the steel. Fig. 19 shows the structure of file steel which had been finished at too high a

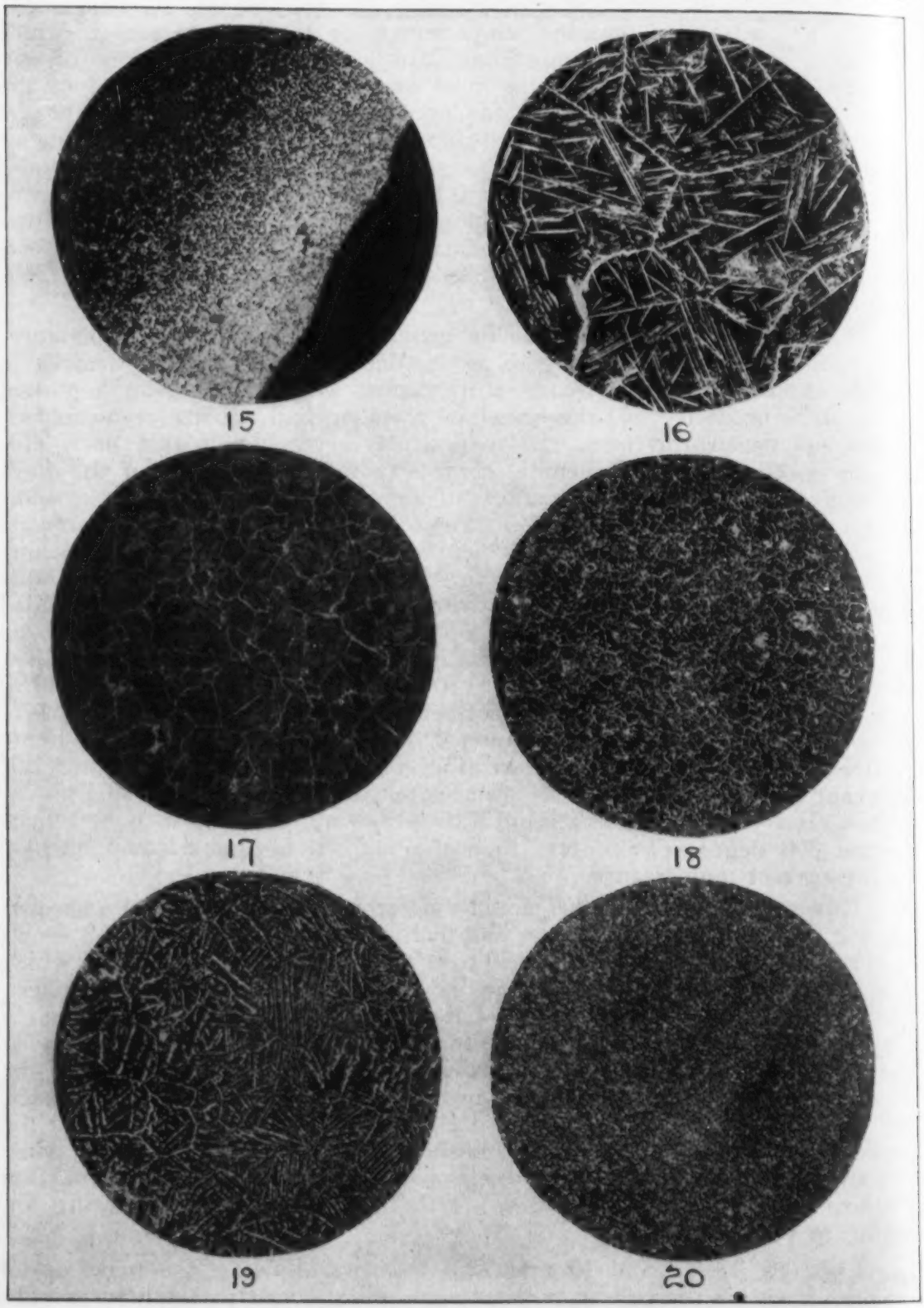


Fig. 15—Structure of 1.15 per cent carbon knife blade steel seriously decarburized in mill furnace. Etched with 10 per cent nitric acid and X 120. Fig. 16—Cast structure of 1.40 per cent carbon file steel. Etched with 10 per cent nitric acid and X 120. Fig. 17—Structure of file steel of Fig. 16 after being cogged down in three passes, evidences of cast structure still showing. Etched with 10 per cent nitric acid and X 120. Fig. 18—Structure of file steel as it comes from the rolls finished properly and at correct temperature. Etched with 10 per cent nitric acid and X 120. Fig. 19—Structure of file steel finished at too high a temperature and then hardened. Etched with 10 per cent nitric acid and X 120. Fig. 20—Structure of file steel correctly finished in rolling mill and then hardened. Etched with 10 per cent nitric acid and X 120.

temperature and then hardened, and Fig. 20 represents the hardened structure of file steel which has been properly treated and correctly finished in the mill.

From the foregoing it is quite evident that the lack of care in the rolling mill can make the work of the tool steel worker and heat treater very difficult, and also that temperature control is of the utmost importance in the rolling of steel. The finishing temperature is under greater control in the hammering process than in rolling, as stated previously, because the conditions which go to make up the two operations are vastly different. The best temperature for the finishing of rolled steel is at the Ar range of the steel. This may be determined in a number of ways, but probably the simplest means is by the magnet and the condition of the scale. The use of the magnet is based on the magnetic properties of steel above and below the critical stage, since steel above the range is nonmagnetic. The change represented being from the alpha to gamma state. The other method based on the condition of the scale or oxide on the steel, is that when steel has passed through the Ar range, the scale will not lift from its surface during further cooling.

Microscopically the finishing temperatures of steel may be determined by the structure of the cold material, after cooling on the mill floor. Figs. 21, 22, 23, 24 and 25 show the structural conditions of a steel containing 1.10 per cent carbon and finished at different temperatures, with the exception of Fig. 25 which shows the finished structure of a steel containing 1.10 per cent carbon and 1.60 per cent chromium. It has been found that in those cases where the finishing temperature has been so regulated as to produce a sorbitic structure as shown in Figs. 23, 24 and 25, that a simple anneal at a temperature under the critical range is sufficient to produce a high grade annealed tool steel of the kind best suited for the tool maker and treater.

As previously stated normalizing or annealing or both of these treatments are necessary if tool steel is to leave the steel mill in the best condition. Efforts have been made to show why this is so. Normalizing is especially necessary in steels containing alloys such as chromium. One evidence of this fact is seen by referring to photomicrographs, Figs. 26 and 27. Fig. 26 represents the structure of a chromium carbon steel containing 1.72 per cent chromium and 1.34 per cent carbon after being hardened. The steel was first hammered to size, heated to 1600 degrees Fahr. for several hours and slowly cooled in the furnace after which it was hardened. Fig. 27 shows the structure in another place of the same material which was hammered to size, air-cooled, then heated to 1650 degrees Fahr. and air cooled or normalized, and then annealed at 1600 degrees Fahr., or slowly cooled in the furnace and then hardened. The structure in Fig. 26 was produced in hammering and comprises areas of free carbides which did not go into solution with the rest of the material under ordinary annealing. The finishing temperature of the steel was slightly in excess of the Ar range. In Figs. 28, 29 and 30 are shown the structures of chromium carbon steel containing 1.30 per cent carbon and 1.60 per cent chromium which was normalized after hammering and then annealed. Fig. 28 was heated to 1800 degrees Fahr. slowly cooled in the furnace to 1100 degrees Fahr. and then air cooled. Fig. 29 was heated to 1550 degrees Fahr. after hammering and cooled in the furnace, while in Fig. 30 the structure

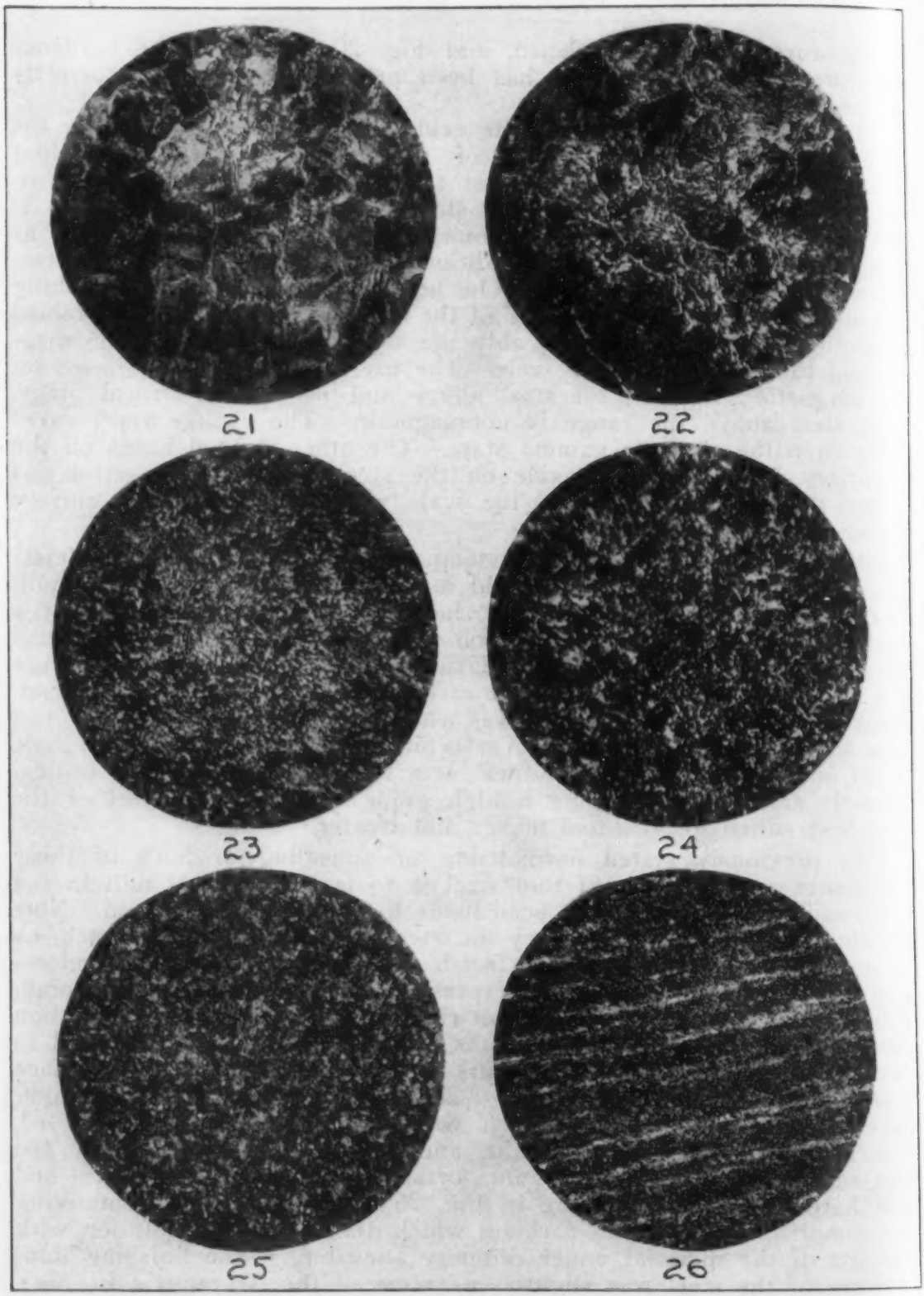


Fig. 21—Structure of 1.10 per cent carbon tool steel finished above the Ar range and showing a pearlitic structure with free cementite. Etched with 10 per cent nitric acid and X 500. Fig. 22—Structure of 1.10 per cent carbon tool steel finished above the Ar range showing pearlitic condition with some sorbite and free cementite. Etched with 10 per cent nitric acid and X 500. Fig. 23—Structure of 1.10 per cent carbon tool steel finished at or near the Ar range showing sorbito-pearlitic condition with little free cementite. Etched with 10 per cent nitric acid and X 500. Fig. 24—Structure of 1.10 per cent carbon tool steel correctly finished at Ar range showing wholly sorbitic condition. Etched with 10 per cent nitric acid and X 500. Fig. 25—Structure of 1.10 per cent carbon, 1.60 per cent chromium tool steel correctly finished in rolling mill. Sorbitic condition. Etched with 10 per cent nitric acid and X 120. Fig. 26—Structure of 1.34 per cent carbon, 1.72 per cent chromium tool steel hardened showing effects of free carbide which did not go into solution with simple annealing after hammering to size. Etched with 10 per cent nitric acid and X 120.

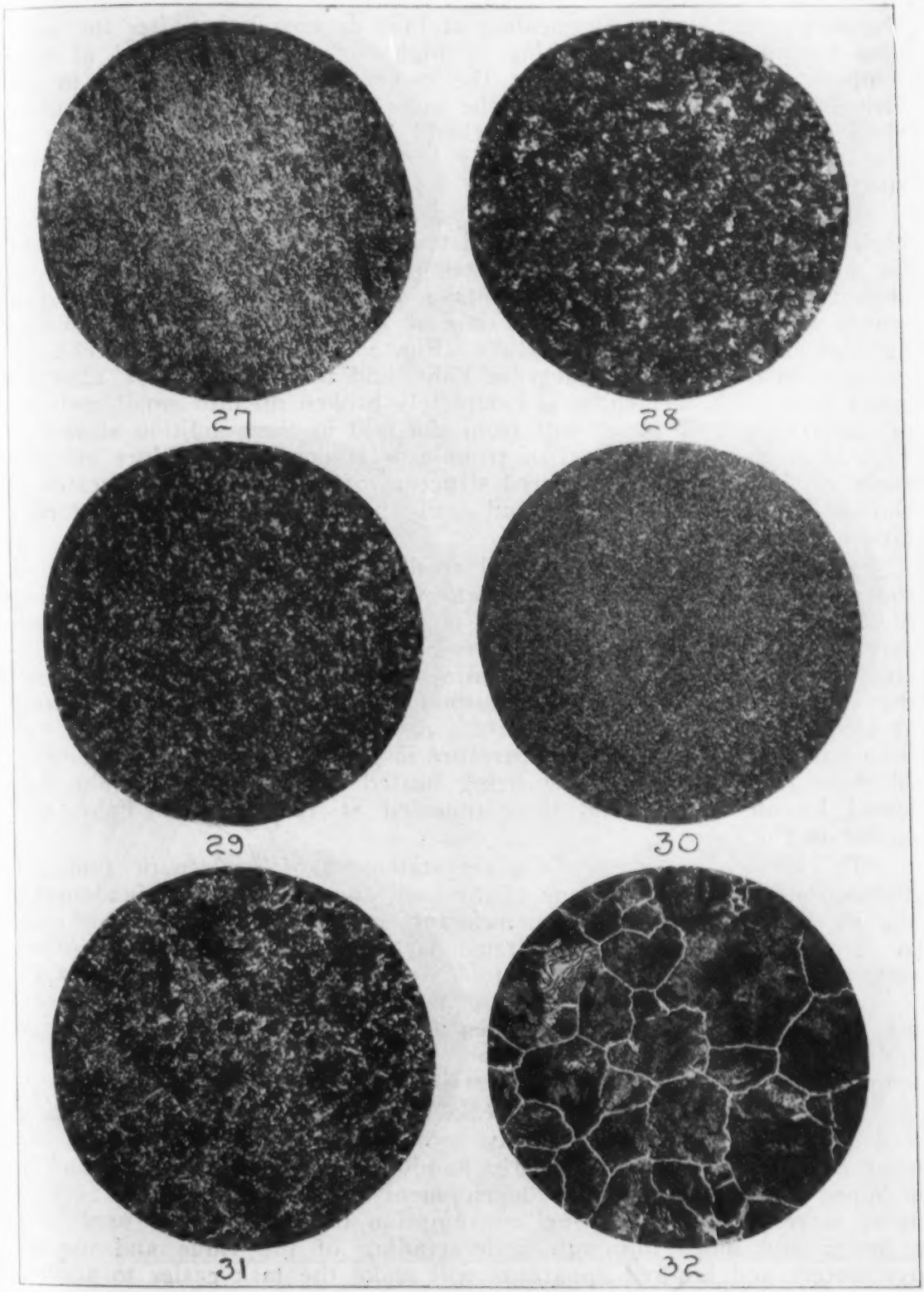


Fig. 27—Structure of same steel in Fig. 26 but which has been normalized at 1650 degrees Fahr. before annealing and hardening. Etched with 10 per cent nitric acid and X 120. Fig. 28—Structure of 1.30 per cent carbon, 1.60 per cent chromium tool steel which has been heated to 1800 degrees Fahr., slowly cooled to 1100 degrees Fahr., and then air cooled after hammering. Etched with 10 per cent nitric acid and X 120. Fig. 29—Structure of 1.30 per cent carbon, 1.60 per cent chromium tool steel heated to 1550 degrees Fahr. and cooled in furnace with door open. Etched with 10 per cent nitric acid and X 120. Fig. 30—Structure of 1.30 per cent, 1.60 per cent chromium tool steel after annealing at 1450 degrees Fahr., following treatments of Figs. 28 and 29. Etched with 10 per cent nitric acid and X 120. Fig. 31—Structure of 1.15 per cent carbon tool steel showing segregated cementite due to high temperature working. Etched with 10 per cent nitric acid and X 120. Fig. 32—Structure of 1.10 per cent carbon tool steel which has been finished at too high a temperature and annealed above the Ac range. A great grain growth shown. Etched with 10 per cent nitric acid and X 120.

shown was produced by annealing at 1450 degrees Fahr. after the previous treatments. The finishing of high carbon content steel at high temperatures sometimes causes the cementite to separate out in the form of longitudinal lines much the same as the ferrite of a low carbon steel forms bands when cold worked. Such a condition is shown in Fig. 31. Normalizing followed by annealing is necessary to correct such a condition.

It is sometimes the case that a steel which has been finished at too high a temperature is annealed at a temperature just over the Ac range for a long time and the grain growth is excessive. Such a condition is shown in Fig. 32. This represents a 1.10 per cent carbon tool steel which was annealed too long a time at 1400 degrees Fahr. after being finished at too high a temperature. Fig. 33 shows the same steel after being normalized at 1500 degrese Fahr. and then annealed at 1250 degrees Fahr. The cementite is completely broken up into small globules or spheroidized. A steel sent from the mill in the condition shown in Fig. 32 causes a great deal of trouble as it does not produce efficient tools. A hardened and tempered structure of the steel poorly treated is shown in micrograph Fig. 34 and easily proves why tools in that condition are practically useless.

The correct structure for tool steels to be placed in the hands of the user has been found to be that in which complete spheroidization of the cementite has taken place. To obtain that structure it is necessary that the finishing temperatures of the steel be carefully regulated for the production of a sorbitic structure. Figs. 35 and 36 show the structures of 1.10 per cent carbon steel which has been annealed at 1350 degrees Fahr., a temperature just above the Ac range. It had been finished at too high a temperature in the rolling mill. Figs. 37 and 38 show the same steel after being heated to 1500 degrees Fahr. followed by air cooling and then annealed at 1250 degrees Fahr. and cooled in the furnace.

This article constitutes a plain statement of facts with sufficient illustrations to bring out some of the easily passed over, but fundamentally important phases of the manufacture of tool steels. The chief aim has been to present these illustrated facts without too much detail of equipment. The preparation of tool steel at the mill has been shown to embody the control of finishing temperatures, normalizing, annealing and the spheroidization of cementite, dependent upon the knowledge and use of the fundamental factors of steel treatment, namely time, temperature, mass, surface, and last but not least, the human element.

The steel mill has at least awakened to the necessity of producing tool steel that will cause the least trouble for the user and make the most efficient tools when properly handled by the steel treater, and it is hoped that the mechanical developments of the future, such as furnaces more economical in fuel consumption than many now used, and a better and more thorough understanding of the value and use of pyrometers and kindred apparatus will make the task easier to accomplish. Such a realization will constitute a marked step forward in the art of steel manufacture and treatment.

Discussion of Mr. Green's Paper

MR. SMALL: I would like to ask Mr. Green a question in refer-

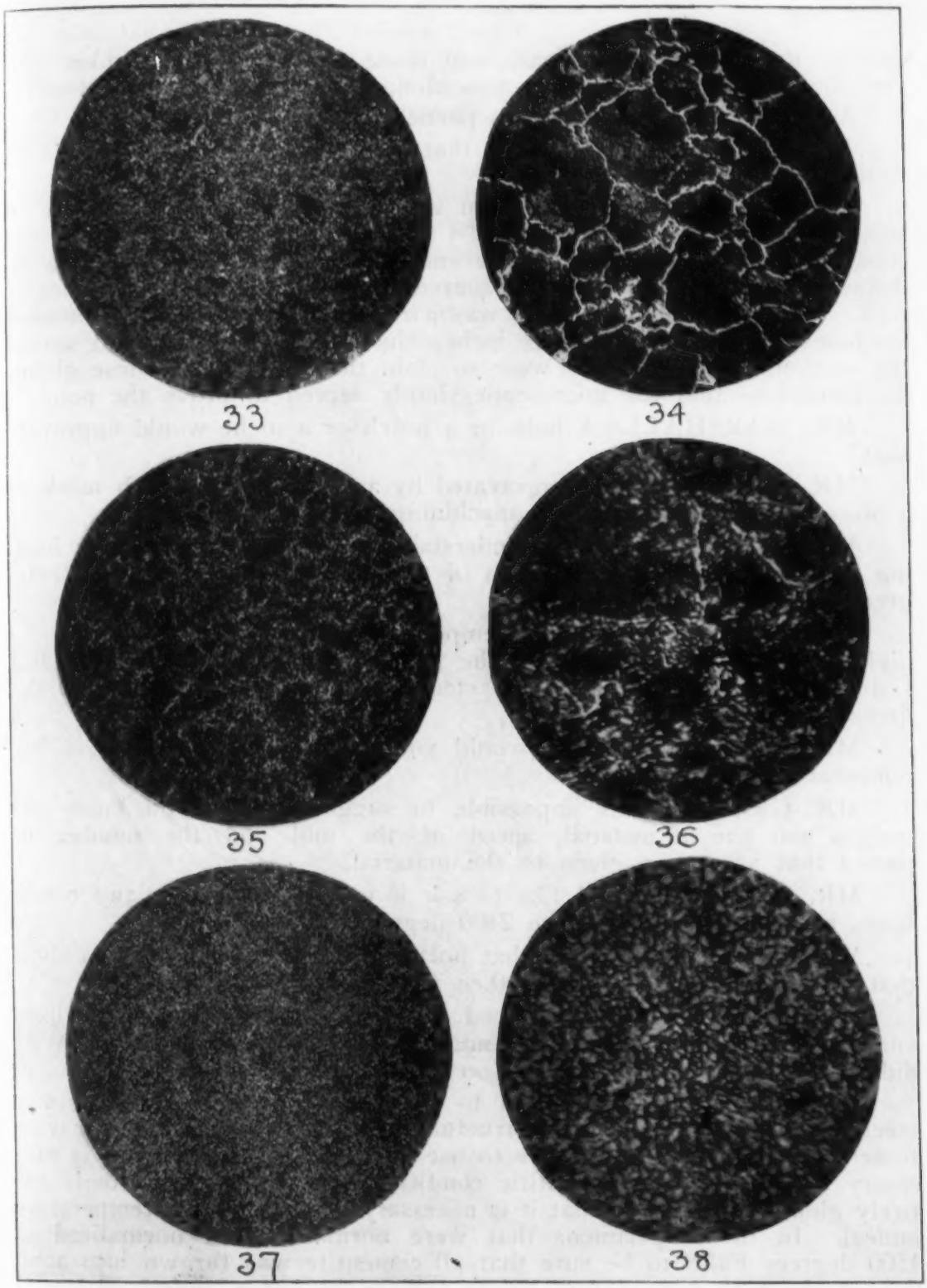


Fig. 33—Structure of 1.10 per cent carbon tool steel shown in Fig. 32 but normalized at 1500 degrees Fahr. then annealed at 1250 degrees Fahr. Etched with 10 per cent nitric acid and X 120. Fig. 34—Structure of 1.10 per cent carbon tool steel shown in Fig. 32 hardened showing large grains which were not broken up by the hardening operation. Etched with 10 per cent nitric acid and X 120. Fig. 35—Structure of 1.10 per cent carbon tool steel which was annealed at 1350 degrees Fahr. after having been finished at too high a temperature in the rolling mill. Etched with 10 per cent nitric acid and X 120. Fig. 36—Same structure as in Fig. 35 but X 500. Etched in 10 per cent nitric acid. Fig. 37—Structure of 1.10 per cent carbon tool steel same as in Figs. 35 and 36 but normalized at 1500 degrees Fahr. and then annealed, showing spheroidized cementite. Etched with 10 per cent nitric acid and X 120. Fig. 38—Same structure as in Fig. 37 but X 500. Etched with 10 per cent nitric acid and X 500.

ence to the cementite segregation in those two pieces that broke. Do you contend that the breaking was along those lines of segregation?

MR. GREEN: It was in this particular case.

MR. SMALL: Do you think that would be true in other cases as well?

MR. GREEN: I see no reason why it shouldn't be. Cementite in straight carbon steels is the hardest and consequently the most brittle constituent, and if you divorce it and throw it out into certain well-defined lines, it is naturally a source of weakness in that particular tool. Now the tool that broke was a round die about 4½ or 5 inches in diameter, and probably 3½ inches thick, and it broke right across the section. The evidences were so plain that it followed those globular conditions that the microscope simply served to prove the point.

MR. MARSHALL: A hole, or a notch or a niche would aggravate that?

MR. GREEN: It was aggravated by a small center punch mark or a place punched for a drill for machining in the lathe.

MR. HOFFMAN: Did I understand you to say that proper forging temperatures for most grades of tool steels were 2100 to 2400 degrees Fahr.?

MR. GREEN: I said the temperatures in rolling were generally higher than in forging. I said the general rolling temperatures. But I don't think you will find tool steel is carried as high as 2400 degrees Fahr.

MR. HOFFMAN: What would you suggest as the proper rolling temperature?

MR. GREEN: It is impossible to suggest unless you know the analysis and size of material, speed of the mill and the number of passes that are to be given to the material.

MR. CROW: I would like to ask if you would, under any conditions, ever heat a tool steel to 2400 degrees Fahr.?

MR. GREEN: I think in that portion of the paper I tried to show that lower carbon steels were taken that high.

MR. D'ARCAMBAL: I noticed on the sample that you normalized and then annealed you always annealed at 1250 degrees Fahr. Why did you go lower than you would on a straight annealing?

MR. GREEN: That is hard to answer. To assure a proper tool steel leaving the mill with a structure that is acceptable to our customers for the work they desire to use it we have found that it is necessary to give them a cementitic condition where the cementite is entirely globular and to do that it is necessary to make a low temperature anneal. In those specimens that were normalized we normalized at 1500 degrees Fahr. to be sure that all cementite was thrown into solution at the high temperature before taking the lower anneal, although I have been able to successfully anneal steel in one operation, where the finishing temperature in the mill has been taken care of and the steel finished at approximately the Ar range, or slightly under.

MR. D'ARCAMBAL: The reason I asked that question was that we were furnishing some steel to one mill and they normalized it and claimed they re-annealed it from 1380 to 1400 degrees Fahr.

MR. GREEN: I don't believe that it is possible at 1380 and 1400 degrees Fahr. to give the steel to the customer in the globular cementitic condition. In fact, I think Dr. Sauveur has brought that matter out in his book, that low temperature annealing is a great help in producing the globular cementite.

MR. D'ARCAMBAL: How do you determine the proper high speed steel finishing temperature with hammering?

MR. GREEN: I haven't done any work with high speed steel.

MR. D'ARCAMBAL: One of the mills was telling me the other day they had some sort of magnetic system, but I didn't know just how magnetism with high speed steel acted.

MR. GREEN: I know nothing about it, and cannot answer your question.

HEAT TREATMENT OF STEEL FOR ORDNANCE PURPOSES

By H. F. Leary

DEVELOPMENT of the arts of metallurgy and metallography has been an important factor in the development of naval ordnance to its present high state of efficiency. The improvements in guns, armor and projectiles have been due largely to the steady development of the science of heat treatment.

It should be understood distinctly that heat treatment is an exact science, and is a means to an end, but that the most scientific heat treatment alone cannot accomplish desired results unless the material to be heat treated is of the proper quality. In other words, too often the heat treatment department has been called upon to doctor up and render satisfactory material improperly melted. In order that the science and results may be exact, the material, when turned over for treatment, must be homogeneous, free from impurities, and carefully melted. For example, if the aim is certain physical properties, these properties might be obtained by a standard thermal treatment in a homogeneous, pure carbon steel, whereas, if the melting methods are not modern and scientifically carried out, it might be necessary to use an alloy steel to obtain results as satisfactory. The necessity for quantity production with the consequent working of the melting plants to maximum capacity, has been detrimental to the development of the quality of production.

Another important point for consideration at the start is that we cannot expect to obtain the same results in large masses that we obtain on small specimens in a laboratory. That is, we cannot compare such results where there are mechanical treatments, or where thermal treatments involve a rapid cooling.

Failure to attain physical properties from a standard thermal treatment is not due alone to the melting, for the mechanical treatment or forging, and the preliminary annealing, or normalizing are also of the greatest importance. Not more than two decades ago, the thermocouple pyrometer was unknown in ordnance work. In the treatment of projectiles and gun forgings the eye of the heater was used, and on the skill of personnel depended the success in meeting physical requirements much as the success of the Damascus steel sword depended on the skill of the workmen.

When test bars showed unexpected failures, it was attributed to flaws or defects without any effort being made to know what these flaws were, or what caused them, and the forgings in question were treated or doctored up in order to meet the requirements. As the requirements of the specifications became more rigid, and as the arts of metallurgy and heat treatment developed, the science became more exact. Steps were taken to prevent grain growth after forging. Preliminary annealing was developed. Buttons were taken, and other metallographic examinations were made to determine whether the material was uniform and properly normalized before proceeding with thermal treatment. Couples were attached to the forging to be treated, and the temperature at various points on the forging recorded, rather than depending on the furnace temperature. Self-recording pyrometers were introduced. The effect of time of heating; holding the heat; the difference in quenching

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A paper presented by title at the Army and Navy session at the Indianapolis Convention. The author, H. F. Leary, is a commander in the United States Navy.

mediums; the time of immersing the steel; the time in the bath and the temperature of the bath, and of the piece when withdrawn, were all studied and recognized as of importance in obtaining the desired results. The theory of stress accumulation was considered, and the necessity for avoiding undue strains. The geometric condition of the forging was studied. The skin effect and the necessity of preliminary machining before quenching was also recognized.

The question of saving in weight has been a vital one, and a careful study has been necessary to determine the strength; the necessary factor of safety of a part; and how this required strength may be developed in as light a piece as possible. The torpedo is an example of the necessity of saving weight, where the mechanical design has developed a torpedo capable of running more than 5 miles at high speed. This would have been impossible had it not been practicable to build a steel air flask 10 feet long and 21 inches in diameter which would safely contain air compressed to more than 5000 pounds per square inch.

In general, the specifications covering ordnance material do not specify the heat treatment to be given. The physical and chemical requirements are specified in detail, and provided tests demonstrate the suitability of the material, it is considered satisfactory. However, there are certain general requirements regarding heat treatment which are incorporated in the specifications with the idea of insuring uniformity of the material and preventing injury through improper treatment.

These requirements include such specifications, as in the case of forgings, that they must be rough machined before treatment; that complete records of treatment must be kept; that in the case of castings, rapid cooling can be permitted only in certain cases specifically approved, and that they must be carefully annealed. In certain cases it is specified that quenching shall or shall not be permitted in the case of forgings, but it has not been the practice, as in some commercial specifications, to specify temperatures that shall be used.

The ordinary physical tests specified are tensile, bends, and in some cases Brinell and scleroscope. All these tests are static tests, and it would seem important to develop some form of dynamic test, inasmuch as the material is of a class which must withstand severe shock. The fact must not be overlooked that upon completion, the material is subjected to a ballistic test. The gun is proof fired at pressures greatly in excess of service pressure, the mount is proved, the torpedo is fired on trial runs, and the armor and projectiles are subject to ballistic test.

In all work in connection with gun mounts, it is essential that the castings shall be free from stresses, and of a composition and treatment which would exhibit shock resisting qualities. The fact that these castings are always rigidly inspected for blow holes and other flaws common to castings necessitates their being melted carefully, and this care tends to uniformity which renders them susceptible of responding to proper heat treatment. In the larger castings it has been necessary generally to use a nickel steel alloy in order to insure the physical requirements. Care must be taken both in inspection and manufacture to insure that the treatment is such that the entire casting will receive the heat, and that the piece is properly disposed in a furnace to effect this.

Gun yokes for even the largest caliber guns have been made of steel castings. In some of the earlier cases, fracture occurred on proof of the gun, and revealed an ingot structure even though successful tests had been made from coupons. This shows how little coupons can be

depended upon, unless the piece has been properly disposed in the furnace, and the treatment properly conducted by pyrometric control.

In general, coupons of ordnance castings must be attached to the body of the casting and not gated on. In small castings, it is more preferable where representative testing is resorted to, to cut up castings selected at random, taking tests from the body of these castings. Manufacturers desire to attach coupons so that they can be broken off readily in the foundry without the necessity of machining, but in this case the area of radiation on the coupon is much greater than the area through which the coupon can receive heat from the casting during cooling, so that the coupon will pass more rapidly through the critical range than the body of the casting, and therefore, in the majority of cases, gives false results on the physical tests. On large castings it would be a good practice to machine out test specimens wherever there is sufficient metal to insure that the treatment has been effective, unless the treatment has been properly supervised.

In the old days when guns were cast, their effectiveness was limited by the pressure that they would stand without bursting, and the only way to increase their strength was to increase the thickness of their walls. After a certain limit of thickness was reached, no increase of strength could be obtained. The built-up gun resulted.

The improvement in the effectiveness of our naval ordnance guns has kept pace with the development of the art of heat treatment by the introduction of alloy steels and careful heat treatment. We have been able in the past 20 years to increase considerably the physical requirements of the steel from which guns are built, and when the art developed so that enormous ingots could be cast successfully and homogeneous enough to be heat treated so that they met our requirements, it became possible to manufacture the largest possible caliber guns. It is doubtful whether a 16-inch 50-caliber gun could have been manufactured successfully under the specifications of 20 years ago, even though the ingots could have been cast of that size, and the mechanical equipment was available for the manufacture.

Specifications for gun forgings for the army and navy are alike, and are covered by a complete booklet. Numerous paragraphs are given regarding raw materials, discards, and size of ingots in order to insure that the material to be heat treated shall be of the best possible quality, and which, together with the requirements for heat treatment, will insure that a rigid treatment is not necessary to obtain the desired physical condition to pass satisfactory test.

No definite process is specified for the steel, but it is specified that the forgings shall be made of domestic steel manufactured from the best quality of raw material and by an approved process. Successful forgings generally have been manufactured of acid open-hearth steel, and it is believed that outside of the electric furnace, the best results are obtained by this process. The reason for this appears to be that the acid process gives the most homogeneous steel with greater freedom from oxides, segregation of the metalloids and other impurities.

Cases have been found where manufacturers endeavored to use ingots made by the basic process. Although the mechanical and heat treatment was such as would have insured success on an acid ingot, failure on physical test has resulted in one or more of the test specimens taken, and ultimately caused the manufacture to be made of acid

steel. In some cases alloy steel ingots were used, the ingots being similar to those from which satisfactory commercial forgings are made.

No requirements as to chemical composition are imposed, other than specified in maximum sulphur, phosphorous, and copper content. Certain forgings are made of what is defined as gun steel, which is a simple carbon steel. Where alloy steel is specified, a simple carbon steel is meant with such percentage of the alloy added as is necessary to obtain the required physical properties.

The physical properties specified vary from 86,000 pounds per square inch tensile strength, 46,000 pounds elastic, 18 per cent elongation, and 30 per cent reduction of area, to 95,000 pounds per square inch tensile strength, 65,000 pounds elastic limit, 18 per cent elongation, and 30 per cent reduction of area. While these properties are exceedingly easy to meet in small forgings, it is a difficult matter to manufacture and heat treat forgings of the largest size so as to exhibit these properties uniformly. The location and number of test specimens is such as to cover the area of the cross section of the forging, and to insure that the desired properties are obtained throughout the mass. It is of interest to note that in all cases of physical test, the elastic limit, or limit of proportionality, must be obtained by the use of a micrometer extensometer.

In the case of the largest forgings, four test specimens are taken at each end of the forging and are slotted out and so located as to cover the outer, middle and inner portion of the forging. In the case of failure of any of these test specimens, which are taken tangentially or transverse to the axis of the forging, a replace bar is laid out in wake of the failing bar and closer to the finish line, and the obligation is placed on the manufacturer to provide sufficient metal to cover all the necessary tests. To insure that the greatest care will be taken in the heat treatment of our gun forgings, it is required that the manufacturer shall assure himself by trial test specimens that the material is in proper condition before it is submitted, and the number of submissions is limited.

In rare cases, if the history of manufacture, treatment and test bars warrant, additional tests may be allowed, but in such cases a full number of bars are taken with such additional ones as are necessary to cover the location of all bars which have previously failed, and it is seldom that such a forging is ultimately accepted. Experience in testing has shown that the greatest percentage of failures is due to impurities in the nature of ghost lines and other segregations in the forging. This is indicated by an irregularity in the results of test specimens, and the fact that further treatment and test may result in the acceptance of the forging, is believed to be due to the decrease in the amount of these impurities from the end of the forging in getting closer to the finish line.

In locating test specimens, all prongs or extensions should be avoided and gone well back of, as these projections invariably present greater radiating surfaces, with a probability of being in a better condition of structure than the mass of the forging. There is in forgings of this nature a marked skin effect in treatment, and it is therefore specified that test bars shall be laid out so that their axis is a definite distance in from the surface which would prevent any effect on the physical properties. This effect has been noted to a marked extent in cases where it was endeavored to show that the structure was uniform throughout the mass by making metallographic examination at various points on the surface of the forging, and comparing the structure with the structure

found in the threads of test specimens. Little or no ferrite will be found in the grain boundaries close to the surface, whereas at a short distance inside the regular structure will be found. That the forgings are believed to be uniform when finished is due to the considerable machining after heat treatment.

The specifications for gun forgings require that as a preliminary treatment, forgings shall be annealed from a temperature above the upper critical, or Ac_3 point, after forging and before quenching. The precautions taken to prevent the rapid heating, and the length of time during which the forging is held at a treatment temperature, must be satisfactory to the inspector. Preliminary annealing may be conducted before rough machining. Every operation of heat treatment shall, if desired by him, be witnessed by the inspector, and if unsatisfactory in any way additional treatment may be ordered. The contractor shall keep records showing for each heat treatment:

(a) The time at which the forging was put in the furnace, and the furnace temperature.

(b) The time occupied in reaching the temperature required in the operation; the temperature so reached; and the length of time the forging is held at that temperature.

(c) The time at which the forging was taken from the furnace in annealing or drawing, and its temperature at that time.

(d) The elapsed time of immersion of both muzzle and breech end in the quenching medium; the quenching medium used, and the temperature of quenching medium before and after immersion.

The contractor is required to provide himself with self-recording pyrometers for measuring the temperatures actually used in heat treatment, and calibration is required. It is believed necessary on long forgings to keep a record of the temperature at various points, and the couples are placed in direct contact with the forging. Where differences in temperature are shown, they must be included in the records.

No annealing ever is permitted on any part of a forging, and the cooling is required to be uniform in a closed furnace and the forging not removed from the furnace until the temperature of the piece is below 600 degrees Fahr. All long forgings are required to be heated and quenched in a vertical position, and arrangement must be made to insure a flow of quenching medium through the bore. The last operation on every forging shall be a draw and should it be necessary to vary the temperature between the ends of the furnace, this variation must be uniform from end to end. Rigid requirements are deemed necessary regarding straightening of forgings.

Gun forgings are so designed as to have sufficient strength in the gun after assembly by shrinkage to withstand the highest proof pressures without any distortion. After the discard is made, the forgings must be so forged and mechanically treated that with a bored or punched ingot the walls are reduced at least 50 per cent. Similar requirements are specified for solid forgings, making an equivalent allowance for upsetting operations.

It is customary after forging to conduct a preliminary anneal and examination, to insure that a normal, uniform structure has been obtained. After rough machining, it should then be sufficient to obtain the desired condition by a simple quench and draw. If conditions have been such that this quench and draw leaves the metal too hard, as shown by trial test specimens, another draw would be given at a suffi-

ciently high temperature which experience would show to be necessary to obtain the desired results. If the forging is found to be too soft, it is necessary to quench it again at a higher temperature, or to quench at the same temperature and draw at a lower temperature than the previous draw. In such cases, all the test specimens taken should be uniformly high or low, or at least uniform as regarding those taken from one end. Where different physical properties are found at each end of the forging, the problem is somewhat more difficult and might involve the necessity of again normalizing the structure before a requench. In all cases, the breech end of the ingot is to be the breech end of the forging. The structure found in gun forgings generally is sorbitic with the grain boundaries plainly marked with uniformly distributed ferrite. In certain cases, needles of ferrite are found penetrating the sorbite grains in geometric form. This may be a persistence of the ferrite in the structure caused by the quench, and while this is not considered a desirable structure, it has not been shown by any test to be unsatisfactory.

Generally there is a considerable increase in the amount of ferrite in the boundaries in going toward the center of the forging, but this is seldom marked enough to cause a difference in the physical properties. While, of course, it would be desirable to develop some form of shock or fatigue test for gun forgings, the fact that the guns successfully pass the proof test and fire successfully at pressures greatly exceeding the service pressures, is believed to insure their suitability. Believing that a cold bending test could be adopted in addition to the tensile test requirements, experiments were conducted some time ago and it was found that in nearly all cases of successful forgings, 180 degree bends could be made flat successfully without fracture, showing that the metal was extremely tough. Successful bends were made about a radius on specimens that exhibited a ghost line structure. This ghost line structure has been a matter of great interest in gun forgings. The tensile physical test is a static test, and static tests, such as the tensile and bend, do not indicate that such structure is detrimental. A dynamic test would be a more suitable test to show its unsuitability, and it is believed that such tests have been made and show conclusively that such a condition is an inferior one.

Where streaks of ghost lines are found in the forging, they generally are surrounded by good metal, and the factor of safety is so large that in the case of most large forgings, they were not believed to be detrimental. Where ghost lines are found on the surface, they are examined metallographically and their extent can be noted by making a metallographic examination of the forging at the end where they appear simply as dots. Many rejections, however, have resulted from this cause, because such flaws are considered evidence of the doubtful value of a forging.

The ghost lines or streaks in large forgings are interesting as they depend somewhat upon the method of manufacture of the steel. They are of two general classes: First, with fine grain and a ferrite predomination; and second, with large grain and absence of ferrite. Inclusions predominate through the streaks, often of a size visible to the eye without magnification. These inclusions generally are believed to be manganese sulphide and silicate and where segregated have always been regarded with suspicion. Later development tends to the belief that the most dangerous element in the steel is the oxide, which appears only as specks under high magnification, but which settles in the ferrite bound-

aries and weaken the adhesion. It is to the electric furnace that we must look for improvement in this respect.

In the early days, projectiles were made of cast steel and later they were forged. Still later, it was found that by reheating them after forging, an increase in the effectiveness was produced, and when the necessity for penetration of armor developed, the points were chilled in the beginning by casting the point in a chilled mold. Later, as heat treatment was studied and introduced, coupled with the introduction of alloy steel, the projectile passed armor in effectiveness.

With the development of the cap for projectiles, the point could be made still harder without breaking off, so it has been a race constantly between armor and projectiles, and with each new development in one, developments and improvements have resulted in the other. The development in the art of heat treatment primarily brought about this competition and improvement.

Armor-piercing projectiles are generally manufactured by the acid open-hearth, or electric furnace. The shape of the ingot varies with the manufacture, as well as the forging methods. The melting is given the greatest care. It is believed that the first really successful armor plate projectiles were made by the crucible process. They are made of alloy steel with various hardening elements added. The greatest care must be given in melting, and in the heating and the forging operation, care being taken to prevent the formation of a core, and to insure that the metal is worked throughout its mass. This forging operation must be carried on to as low a temperature as possible to prevent grain growth. Following forging, the projectiles are given a preliminary anneal and steps are taken to insure that they are normalized. They are then rough machined nearly to size and given a series of quenchings in oil with drawing operations following for the purpose of refining the grain structure and obtaining a quality known as fiber.

The operation of heat treating the forward end of projectiles for hardness is one of great refinement, and one which is held secret by the various manufacturers. It is accomplished by a graduated heating beginning with the point, followed by a complete quench in agitated cold water. This puts the entire projectile in exceedingly hard condition. The heating for this treatment is accomplished generally in a bath of molten lead to insure accurate control of both temperature and position and application of the heat. After this, the base of the projectile is heated to a lower temperature than was used for quenching, and upon withdrawal from the bath or furnace, is suspended nose down and immersed in agitated cold water, which draws or tempers the rear portion while preserving the hardness in the head. The point of the projectile is covered by a cap, which is annealed and fibered. The cross section of a projectile ingot, as well as the cross section of a finished projectile, which has been split open, presents as fine a structure as could be found in any class of steel.

When armor was first made, it was of wrought iron, and the only way of obtaining increased resistance to attack was by increasing the thickness. In some cases, armor was made 2 feet or more in thickness, and the weights were so enormous that relatively small protective area could be given a ship, but even then the crude old fashioned chilled-point projectiles found their way through this armor at the existing battle ranges. There then was developed compound armor which consisted of a bessemer steel plate on a wrought iron back, and some thought was

given to treatment. Later on, the development of face-hardened armor, placed armor ahead of the projectiles and greatly decreased the necessary thickness of armor, permitting much greater areas to be protected on ships. As the development of treatment of armor progressed, coupled with the introduction of alloy steel and toughening and hardening elements, the thickness further decreased, and the saving of weight thereby allowed the introduction and improvement of other offensive and defensive elements entering into the construction of a ship of war.

The heat treatment of armor is of great interest because the modern armor plate probably calls for the largest size ingot, and is probably the greatest mass of steel heat treated to high properties. It is to be regretted that the present processes are by necessity of a confidential nature, as the matter of their mechanical and heat treatment is most interesting. The process generally used is a modification of the Krupp process. When it is considered that casting alloy steel ingots weighing 400,000 pounds is the first step in this process, it can be appreciated with what tremendous difficulties the armor maker is confronted, especially when it is considered that upon the completion of a quantity of about 500 tons of armor, representing twenty or more plates, the acceptance of this group of armor depends upon the successful ballistic test made upon one of these plates selected at random.

A typical analysis of a modern Krupp cement plate is as follows: Carbon 0.35; nickel 3.90; chromium 2.0; manganese 0.35; silicon 0.07; phosphorus 0.025; and sulphur 0.020 per cent. The ingots are made of basic open-hearth steel. The ingot is stripped while still hot, cleaned and charged in a furnace to be brought to a forging heat, in order to save as much of this great amount of heat as possible. It is probable that the center of the ingot is still plastic when the outsides are below color, and in the furnace the heat is uniformly distributed before the forging operation. The ingot is then forged under a powerful hydraulic press to within about 15 per cent of its final thickness, and the discards taken. The plate must then be annealed to eliminate forging strains and to endeavor to normalize the structure. As in the case of the projectile, various treatments follow to insure the desired grain refinement. The ingots are then placed in carbonizing furnaces, and the surfaces super-carbonized to the desired amount, after which the plates are reforged to the desired final thickness. After this operation an annealing process is necessary to prevent cracking while cooling. The face of the plate must be specially heated and chilled under a spray in order that finally the surface of the plate shall be hard and the back tough. The condition of the plates are inspected by drilling to find the depth of the chill, by hardness tests, by fracture tests, and by physical tests.

In conclusion, it can be said that modern ordnance requires the application of the art of heat treatment to the fullest extent in order to attain the results desired in its armor, projectiles and guns, and skill and knowledge of the art is necessary in the manufacture of all the component parts of the innumerable mechanisms demanded by other branches of ordnance. As heat treatment progresses so will ordnance continue to develop as in the past.

EFFICIENCY OF DIFFERENT MIXTURES FOR CYANIDE HARDENING AND THE ROLE OF NITROGEN IN THE PROCESS

By Victor E. Hillman

ACCORDING to present day usage, the term cyanide hardening implies that the steel is immersed in a bath of molten sodium cyanide, allowed to remain therein until sufficient carbon has been absorbed to effect surface hardness, and then subsequently quenched in either oil or water. The aforementioned thermal and chemical treatment produces a skin hardness that will resist abrasive action to a remarkable degree.

The process has its limitations and its own particular sphere of usefulness. Notwithstanding, it has found extensive application where depth of case is not a prime requisite. To the lay mind, cyanide hardening implies that potassium cyanide is used. In recent years, however, sodium cyanide has been substituted with marked success, due to the fact that sodium and potassium belong to the same family, and possess similar properties in combination with the cyanogen radical.

Sodium cyanide has a cyanogen content of 51 to 52 per cent, whereas, the potassium salt contains approximately 38 per cent cyanogen. The carburizing action of liquid cements is generally attributed to the presence of the cyanogen radical. Therefore, the value of the sodium compound is apparent.

Sodium cyanide is used in varying degrees of concentration for carburizing purposes. Ninety-eight per cent sodium cyanide is very efficacious as a fusible carburizing medium and the same is true of a standard mixture containing 76 per cent sodium cyanide and the balance sodium chloride. Other admixtures have been placed on the market containing sodium cyanide, sodium chloride, and sodium carbonate. The chloride and carbonate are inert, and do not contribute in any way to the carburizing action of the bath, but their presence increases the melting point of the compound, and thereby renders it better adapted for the purpose designed. Therefore, this paper will deal with three distinct classes of cyanide hardening mixtures, namely: 98 per cent sodium cyanide, 76 per cent sodium cyanide, and 27 per cent sodium cyanide.

The performance of a cyanide compound containing an admixture of 27 per cent sodium cyanide, 16.8 per cent sodium chloride, and 54.5 per cent sodium carbonate was observed under actual working conditions for a period of three years. Certain operating difficulties were in evidence from time to time, although they proved to be of little or no consequence.

Just before the compound reaches the desired temperatures, 1475 degrees Fahr., a black viscid coating forms on the surface of the liquid. Further heating, however, produces a clear molten bath free from floating scum. The black charred mass which arises to the surface of the liquid is unquestionably an admixture of graphite and sodium carbonate and this salt manifests a tendency to separate from the remaining ingredients at a low temperature. The blackening of the carbonate is occasioned by the presence of graphitic particles which are liberated from the cast iron container. If an attempt is made to operate the bath at 1300 degrees Fahr. or thereabouts, a scum will also be in evidence.

The presence of sodium chloride (common salt) and sodium car-

A paper presented at the Indianapolis Convention. The author, Victor E. Hillman, is metallurgist, Crompton & Knowles Loom Works, Worcester, Mass.

bonate (washing soda) exert no carburizing action whatever. They are incorporated with sodium cyanide for four reasons: 1. To cheapen the product; 2, to raise the melting point; 3, to act as "fixitives" which prevent excessive volatilization of the fleeting cyanogen base; and 4, to assist in the decomposition of the sodium cyanide thereby rendering the $(CN)_2$ group more readily available as a carburizing agent. The depth of penetration incident to the use of the subject mixture was determined by keeping the temperature of the bath constant at 1475 degrees Fahr., and varying the length of time that the specimens were allowed to remain in the liquid cement.

Forty-eight pieces of steel 5/16-inch square and 1-inch long were immersed in the molten compound and duplicate sets of specimens were withdrawn and quenched in water at 5-minute intervals up to the first hour, and every 10 minutes after that. The duration of the entire test consumed exactly three hours. Admittedly, the three-hour period is of no practical value, although it is instructive to observe the effect of the prolonged carburizing treatment.

Material of the following analysis was used for determining the depth of penetration: Carbon 0.15; manganese 0.50; sulphur 0.09; and phosphorus 0.12 per cent. Commercially this steel is known as screw stock. It has low carbon, and high sulphur and phosphorus. The steel is used for its free-cutting qualities when smoothness of finish and high production are required. The majority of articles which are cyanide hardened are made from this grade of steel on the automatic screw machines, hence, the reason for its selection for test purposes.

The case is composed of two distinct fields, namely, a martensitic outer zone, and an inner troosto-sorbite area of lesser carbon content. The depth of case is ascertained by measuring the distance from the outer edge of the specimen to the center of the second zone. In passing it may be of interest to mention that the etched microstructure of the case possesses a yellowish tinge in contradistinction to the jet black appearance of the zones produced by solid cements. The specimens were polished and subsequently etched in a 5 per cent solution of nital. Measurements were taken with the aid of an eyepiece micrometer, which was standardized against a scale of known calibration.

Curve *A*, Fig. 1, illustrates the depth of case penetration obtained by subjecting low carbon 0.15 per cent steel to the carburizing and nitrogenizing action of a 27 per cent cyanide mixture. Note that there is a gradual development of the case during the first hour of immersion. Subsequent penetration is retarded, however, in view of the fact that the shell after becoming saturated, prevents the ingress of additional carbon and nitrogen. After the first hour, the curve gradually slopes toward the horizontal until the completion of the test.

Inasmuch as the immersion period for commercial cyanide hardening generally is 30 and seldom exceeds 60 minutes, the discussion of the curve will be confined to the one-hour period. When steel is cyanided for 30 minutes in a 27 per cent mixture at a temperature of 1475 degrees Fahr., the depth of penetration amounts to approximately 0.04 inch; whereas, the width of the case is proportionately less when the time factor is reduced.

On the other hand, one-hour immersion produces a layer nearly equivalent to a depth of 0.07 inch. It should be borne in mind that the size of

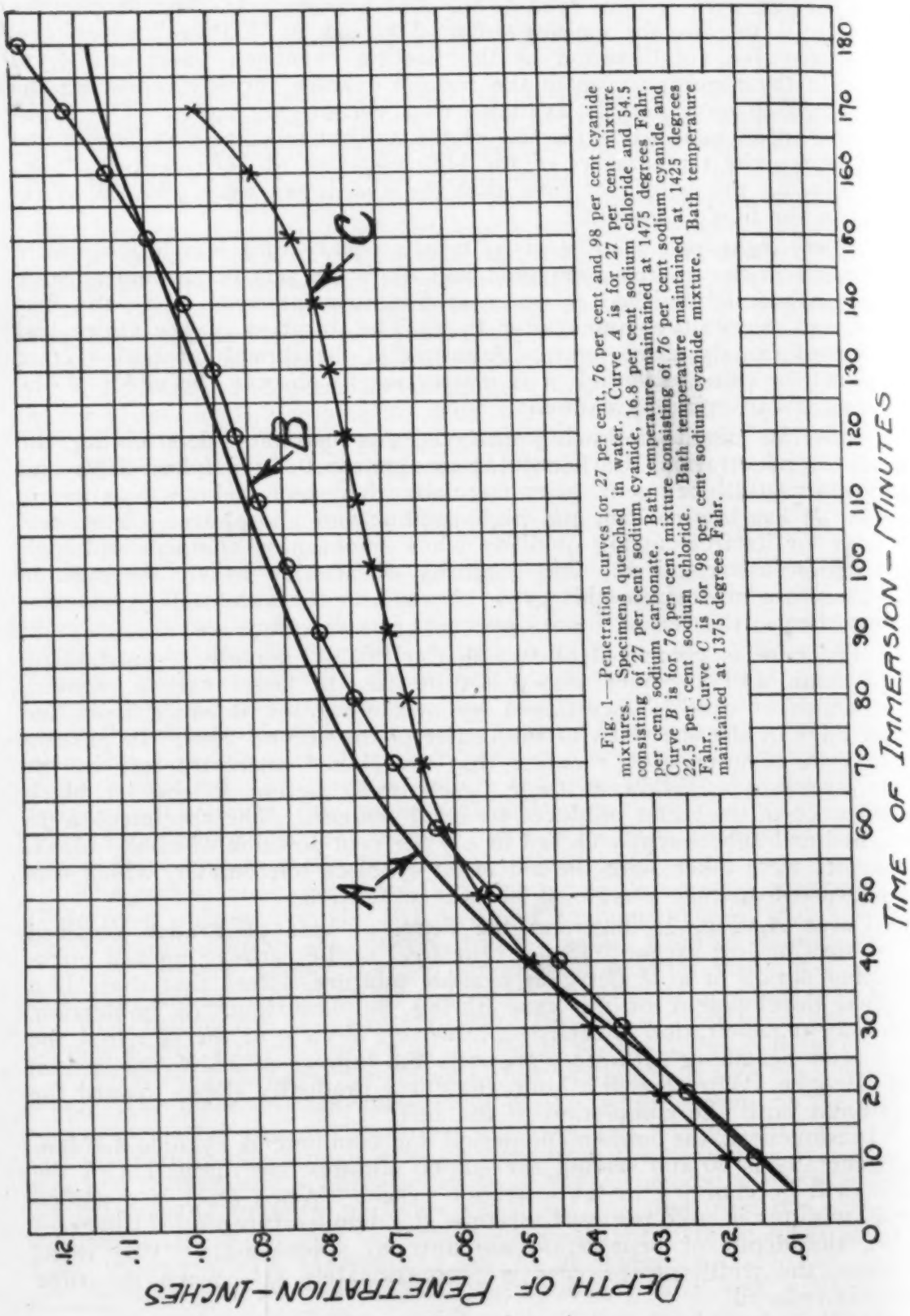

Fig. 1—Penetration curves for 27 per cent, 76 per cent and 98 per cent cyanide mixtures. Specimens quenched in water. Curve *A* is for 27 per cent mixture consisting of 27 per cent sodium cyanide, 16.8 per cent sodium chloride and 54.5 per cent sodium carbonate. Bath temperature maintained at 1475 degrees Fahr. Curve *B* is for 76 per cent mixture consisting of 76 per cent sodium cyanide and 22.5 per cent sodium chloride. Bath temperature maintained at 1425 degrees Fahr. Curve *C* is for 98 per cent sodium cyanide mixture. Bath temperature maintained at 1375 degrees Fahr.

the part which is being treated has a direct bearing upon the time factor of immersion. Penetration commences from the moment that the steel passes its lower critical range. Therefore, due allowance should be made for the period which is required to bring the article to the absorption temperature. The mixture mentioned previously should find extensive use in the production of a superficial case such as is required on articles subject to light wear. Moreover, the compound serves as an excellent heating medium.

The fumes which arise from the 27 per cent mixture are not dangerous, although they are decidedly obnoxious inasmuch as they irritate the mucous membrane in the nasal passages and thereby produce violent sneezing. The lachrymal glands also appear to be affected, in view of the fact that a copious discharge of watery fluid passes from the eyes and nose of workmen who are unnecessarily exposed. The fumes consist mainly of sodium carbonate, sodium cyanate, alkali chlorides, and a small amount of cyanide.

If hoods are installed over the cyanide furnaces and connected to suitable fans, the fume nuisance is abated. Good ventilation is of prime importance also. A prominent medical authority says, "Broadly speaking, constant exposure to any chemical compound is likely to be injurious to health particularly if it is likely to give rise to dust, fumes or gas," and...."an abundant supply of fresh air is the best method of protecting the health of the worker."

The carburizing action of a compound containing 76 per cent sodium cyanide and 22.5 per cent sodium chloride was determined by precisely the same procedure followed in the previous tests, save for the temperature of the bath. It is not feasible to operate the 76 per cent mixture at a temperature in excess of 1425 degrees Fahr. due to excessive volatilization, of the cyanogen base.

Curve *B*, Fig. 1, illustrates the effectiveness of the subject matter. As in curve *B* there is a gradual development of the case for the first hour of immersion, after which the velocity of penetration is somewhat retarded. Moreover, the 30 minute and 60-minute specimens yield measurements which are nearly identical with the results obtained from the 27 per cent mixture. It appears that the higher concentration of the cyanogen radical does not in any way contribute toward the efficacy of carburization. This is occasioned, first, by the necessity of operating the 76 per cent bath at a lower temperature and second, by the fact that the cyanogen content of the 27 per mixture is more than ample to satisfy the saturation point of the metallic charge. There is no doubt, however, but that the 27 per cent compound will have to be replenished oftener. It is a well recognized fact that fusible cyanides become impoverished by continual use.

Curve *C*, Fig. 1, is representative of the carburizing action of commercial sodium cyanide. Inasmuch as the melting point of this mixture is 1004 degrees Fahr., it is mandatory to confine the operation of the bath to a temperature of approximately 1375 degrees Fahr. There is no particular advantage incident to the use of the more expensive compound. It may be noted that for the first hour, the curve practically parallels the slopes obtained from the 27 per cent and 76 per cent mixtures. As the period of immersion is increased, the velocity of penetration is retarded. This may be due in a measure to the increased con-

centration of the carbon in the cemented zones which manifest a tendency to become saturated and thus to prevent the influx of additional carbon.

The size of the pot appears to have a marked influence upon its longevity. Small containers, 6 inches wide, 20 inches long, and 6 inches deep and having ½-inch walls, are serviceable for six to nine months, whereas, the larger pots, 13 inches wide, 25 inches long, and 12 inches deep having ¾-inch walls, have an average life of 21 days. If the pots are suitably reinforced and properly supported, their replacement is not an expensive proposition. Cast iron pots will resist the action of the molten cyanide for a reasonable length of time, providing they are sound, free from blow holes, porosity, and shrinkage flaws.

The writer holds a firm conviction that the life of a cyanide container is a function primarily of molding and casting practice. Various high temperature alloys have been tried and rejected inasmuch as the benefits derived were not commensurate with the increased cost. A gray iron pot, 13 inches wide, 25 inches long, 12 inches deep, and having ¾-inch walls, costs approximately $30 as against $346.25 for a container cast from a special alloy mixture. In certain instances, the high priced receptacles failed after one week's service due to faulty casting practice.

The molten cyanide solution is operated intermittently, that is, the bath is brought to a temperature of 1375-1475 degrees Fahr. and kept at this degree of heat for seven hours, and then it is allowed to cool for the night. Cast iron will withstand the heating and cooling effect of the bath to better advantage than the special alloys.

Alloy containers have a tendency to develop cracks while cast iron fails because of excessive bulging. Moreover, cast iron pots suffer more from the corrosive action of the cyanide than high temperature alloys. In passing, it will shorten the life of any pot. An effort should be made to obtain a neutral atmosphere in the combustion chamber of the furnace, for the cutting action of a highly oxidizing flame is well known.

It is customary to determine the effectiveness of cyanide hardening by resorting to the file test. If the metal has responded to the case hardening treatment, the peripheral layer cannot be attacked with a file. The depth of the carburized surface, however, can be ascertained only by means of microscopic examination.

Brinell and scleroscope values do not give a satisfactory index to the efficiency of cyanide hardened metals for when a specimen is subjected to the Brinell test, circumjacent cracks appear in the vicinity of the depression. The readings obtained are more or less variable, this being due probably to the difficulty which is experienced in reading the diameter of the indentation. The scleroscope, in a measure, is more reliable than the Brinell machine for testing hardened surfaces. The height of the hammer rebound yields fairly concordant results, although there is no appreciable difference between specimens cyanided 5 minutes and 65 minutes.

The mechanism of cyanide hardening has been the subject of considerable controversy. Undoubtedly, the cyanogen radical exerts a nitrogenizing and carburizing influence on the metal. Nitrogen needles were noted in the microstructure of a specimen of low carbon steel that had been subjected to the influence of ammonia, for 100 hours at 1400 degrees Fahr. The presence of similar needles, their length, and orientation was duplicated by immersing a low carbon steel in a 27 per cent cyanide

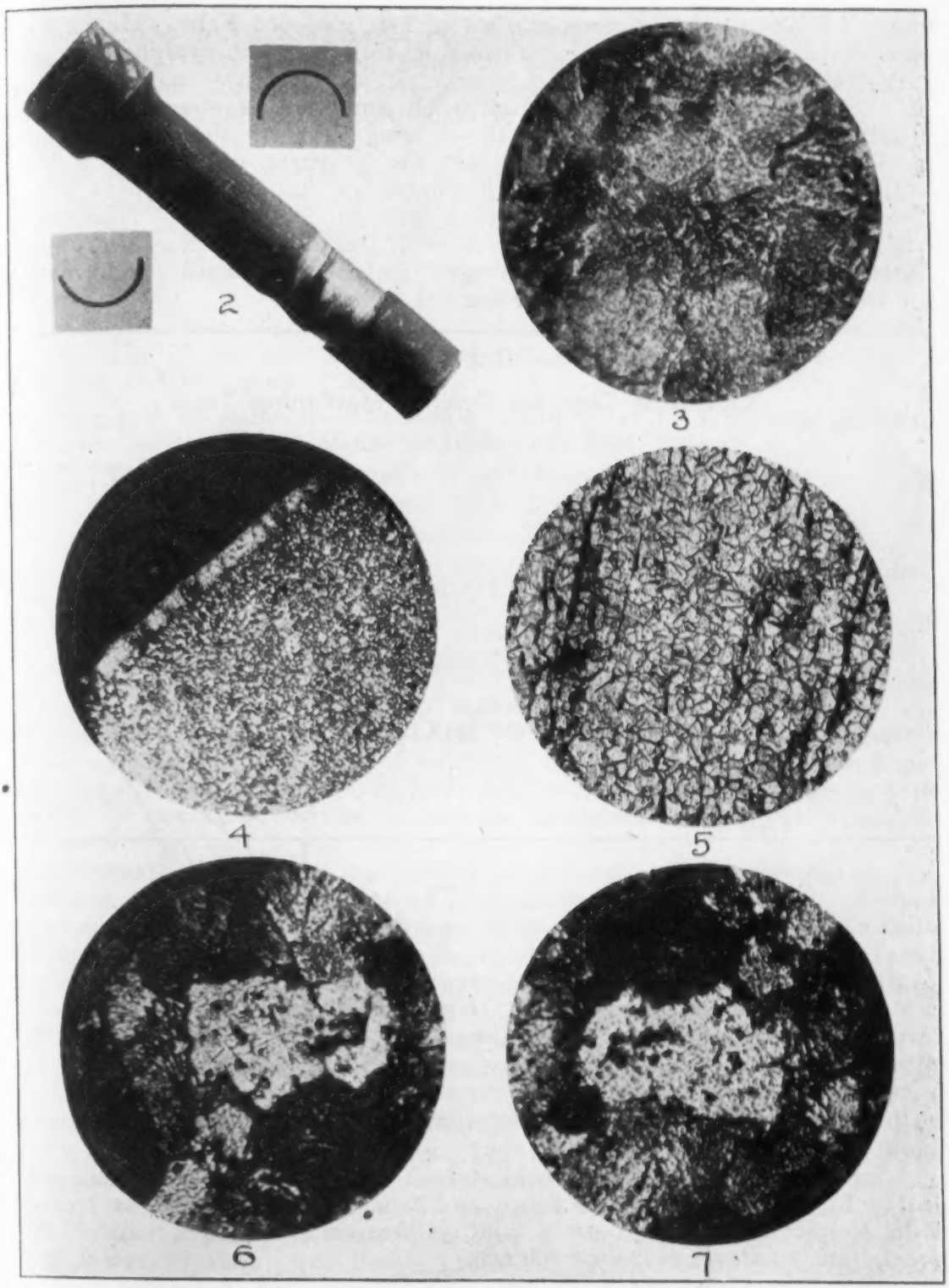

Fig. 2—Specimen treated with ammonia for 100 hours at 1400 degrees Fahr., illustrating power of nitrogen to form a layer possessing similar characteristics to case formed in cyanide hardened steel. Fig. 3—Specimen subjected to influence of cyanogen radical for 32 hours at temperature of 1450 degrees Fahr. and cooled slowly. Note sinuous flakes in center. A similar pattern is obtained in specimens that have been nitrogenized. This irresolvable structure has been designated "flavite." Specimen etched and X 425. Fig. 4—Micrograph showing the appearance of the case, which is 0.054 inches deep. Carburized 45 minutes in 27 per cent mixture at 1475 degrees Fahr. Specimen etched and X 100. Fig. 5—Specimen showing micro-appearance of iron nitrogenized 100 hours at 1300 degrees Fahr. Note Fe_2N needles. Specimen etched and X 100. Fig. 6—Specimen cyanided 32 hours at 1425 degrees Fahr. Note irresolvable pearlite or "flavite." The Fe_2N needles are plainly discernible in the ferrite areas. Specimen etched and X 425. Fig. 7—Specimen cyanided 32 hours at 1450 degrees Fahr. Note irresolvable pearlite or "flavite." Specimen etched and X 425.

bath for 32 hours at a temperature of 1450 degrees Fahr. Hence by a process of elimination, it is reasonable to infer that cyanide hardened articles are nitrogenized.

A specimen that was treated with ammonia is shown in Fig. 2. Broken ringlets may be noted, these being part of the case that was formed. Nascent nitrogen possesses the property of forming a layer which is hard and brittle. The cyanogen radical also produces a case that is hard, brittle, and interspersed with nitride needles. Nitrogen is the only element that is common to both treatments, hence, the natural inference that the influence of nitrogen contributes toward the formation of the case, and the physical properties imparted.

Table I

Operating Data for Cyanide Hardening Tests

MELTING POINT TABLE

	Melting temperature Degrees Fahr.
Sodium Chloride	1472
Sodium Cyanide	1004
Sodium Carbonate	1562

CRITICAL TEMPERATURES OF STEEL USED

	Degrees Fahr.
AR_1	1283
AR_2	1409
AR_3	1562

COST OF MIXTURES

27 per cent mixture	$0.20 per pound
76 per cent mixture	0.25 per pound
98 per cent mixture	0.30 per pound

A number of the cyanide hardened specimens were treated individually with hot hydrochloric acid. The solvent action of the acid was allowed to continue until the case was dissolved and the solution was then made alkaline by the addition of sodium hydroxide and subjected to distillation. The distillate when tested with Nessler's reagent yielded a voluminous brown precipitate ($OHg_2\ INH_2I$), thus the presence of a large amount of nitrogen in the case was definitely established. The nitrogen evidently exists in the case as a nitride (Fe_2N) which is converted to ammonium chloride by the action of the acid, and retained as such until the (NH_3) radical is expelled through the agency of distillation.

Steel specimens in the natural state, that is, not cyanided, were subjected to this analytical procedure and when the distillate was treated with Nessler's Reagent, only a faint yellow color was discernible. No precipitate whatever was in evidence.

The micro-appearance of the unhardened case possesses certain peculiarities. Under low magnification the field resembles pearlite, but differing from that microconstituent in that the dark areas are devoid of laminations when viewed through high power lenses. The same condition is true after the specimens are normalized.

As a matter of convenience this irresolvable micro-constituent has been designated by J. Kirner as "flavite." It is a sinuous mass rich in

nitrogen, responsive to various etching reagents, carbon bearing, and present in articles that are cyanide hardened. Various investigators have analyzed the case formed in cyanide hardening and found that the carbon content varies from 0.30 to 0.60 per cent. A specimen is shown in Fig. 3.

In Table I are shown some of the operating data used in conducting the series of experiments. After extensive investigation the following conclusions regarding cyanide hardening may be drawn:

1. Cyanide hardening is poorly adapted for the production of deep cementation.
2. The depth of penetration increases with the time of immersion.
3. The 27 per cent compound parallels the effectiveness of the 76 per cent and 98 per cent mixtures.
4. It is desirable to incorporate fillers with the sodium cyanide to raise the melting point of the mixture.
5. Cyanogen exerts a carburizing influence while the iron is in the alpha and beta state, that is, from 1375 to 1475 degrees Fahr.
6. The case contains an abundance of nitrogen.
7. Nitrogen possesses the power of forming a microconstituent known as "flavite."

Discussion of Mr. Hillman's Paper

MR. HILLMAN: Prior to making these tests I was under the impression that the depth of cyanide hardening would not increase after half an hour. Many foremen entertain the idea that maximum penetration is obtained after a half hour immersion and any increase in time which the metal is allowed to remain in the carbonizing bath has no influence whatever. I find that to be incorrect.

MR. McCLOUD: I would like to call the attention of the speaker to the fact that it is possible to so combine the sodium carbonate and sodium chloride that you obtain an eutectic mixture which will have a melting point scarcely above that of sodium cyanide, if you used sodium chloride and sodium carbonate in the proportions of 65 per cent carbonate and 35 per cent chloride. I believe that is a close mixture to the eutectic mixture with a melting point of about 1100 degrees Fahr. I would also like to point out, as the speaker has not noted it, the rapid decomposition of sodium cyanide in the pots. I don't know whether Mr. Hillman has had occasion to make any analysis of the baths after they have been in use for a short time, but I know when I first made some determinations of the cyanide and carbonate present in sodium cyanide pots, I was much surprised with the speed of the decomposition. If you start with 76 per cent cyanide, within a few hours it has dropped off and inside of about five hours you don't have 10 per cent of sodium cyanide present in the bath. I think that factor should be considered in explaining the bending of the curve and the falling off in the penetration. Undoubtedly, the explanation that Mr. Hillman has made of the saturation is a factor but I believe my explanation has some bearing.

MR. HILLMAN: Mr. McCloud's remarks have a direct bearing on the case. My experience with the decomposition of the bath has been in accordance with Mr. McCloud's remarks, namely, that you must renew

the bath or your carborizing will become ineffective, if you attempt to operate the same bath over too long a period. Insofar as a layering was concerned, I was under the impression that the various compounds, the chloride, carbonate and cyanide would form three distinct layers when the bath was heated, but that does not seem to be true, because the boiling, or ebullition of the bath, seems to incorporate thoroughly the three compounds into one. At what temperature did you operate?

MR. McCLOUD: I should have stated that my operation was at a somewhat higher temperature, about 1500 degrees Fahr. I also intended to bring out the fact that even 1400 and 1475 degrees Fahr. is a rather low temperature for the treatment of a 0.15 per cent carbon steel, and I believe that even in the production of parts for superficial hardness, these generally being of small size, it is just as well to operate at a temperature where you get a little benefit from the heat treatment.

MR. HILLMAN: The only reason I did not operate at a higher temperature is that the bath is decomposed readily, in fact, the pure salt cannot be operated at a higher temperature. I operate under practical working conditions. These baths have been in operation for three years. Several tons of work have been turned out. It is strictly a production proposition. The only theory I have imparted was contained in the last part of the paper, on the nitrogen and "flavite," which was my only way of explaining the results I found, and of course, they are open to criticism.

MR. BROPHY: You believe that carbon is present in "flavite"?

MR. HILLMAN: Yes.

MR. BROPHY: We have conducted research in the laboratories of the General Electric Co., using pure ammonia. We obtained the dark areas containing no carbon at all—no chance to contaminate the ammonia.

MR. HILLMAN: That is a contribution to the paper. If there is no carbon there that merely substantiates my other statement that nitrogen is the cause of your case. Is that true?

MR. BROPHY: Yes. How much carbon did you find in the case?

MR. HILLMAN: I did not make an analysis.

MR. BROPHY: We found 0.30 per cent. That is not sufficient to account for it.

MR. HILLMAN: I stated in my paper that the carbon varied from 0.30 to 0.60 per cent.

MR. BROPHY: We never found it as high as 0.60 per cent.

FATIGUE OF METALS UNDER REPEATED STRESS

By H. F. Moore and J. B. Kommers

PROGRESSIVE failure or fatigue of steel and other metals under oft repeated stress, is of great interest to designers and users of high speed machinery. Fatigue of structural members has been discussed at various times, but it seems probable that, with the exception of reversed stress members in busy bridges and viaducts, structural parts are in little danger of fatigue failure.

The general problem set for the first stage of the joint investigation was to find out by a series of long time reversed stress tests of various kinds of steel together with careful static tests of the same steels, what relation exists between the static elastic strength of steel and its ability to withstand millions of reversals of stress. A secondary problem was to try various tests commonly used on steel to see whether any of these tests give indications of the ability of steel to withstand oft-repeated stress.

It was decided to continue the scope of this preliminary investigation to ferrous materials, and to choose a series of materials which should be distributed widely among the varieties of steel that are in common use. Table I gives the chemical analyses and reference numbers for the steels tested. It was decided to give as many of the steels as possible at least two different heat treatments. The heat treatments used are given in Table II. It is believed that this series of materials comprises a more complete reconnoissance of the field of ferrous metals than has been attempted in any previous series of repeated stress tests.

Reversed stress tests were the principal series of tests and were supplemented by tests in tension, compression, and torsion. Brinell and scleroscope hardness tests, impact bending and impact tension tests, repeated tests and magnetic tests for homogeneity. The rotating beam type of testing machine was chosen for the basic series of reversed stress tests. This machine is shown in Fig. 1. The machine produces a uniform bending moment on the specimen between the bearings *C* and *D*. This type of machine has been used by many investigators, and the present machine was patterned after that described by F. M. Farmer before the 1919 meeting of the American Society for Testing Materials. Other reversed stress tests were made in bending on an Upton-Lewis machine and in torsion on a Olsen-Foster machine.

For the static tests a 100,000 pound Riehle testing machine was used, for the impact tests a Charpy machine, and for the repeated impact tests a machine constructed at the laboratory was employed. A Ewing extensometer was used for strain measurements in the tension and compression tests, and a detrusion indicator employing an Ames dial was used in the torsion tests.

In the rotating beam specimen it was found necessary to reduce the diameter of the specimen at the middle of its length in order that it should

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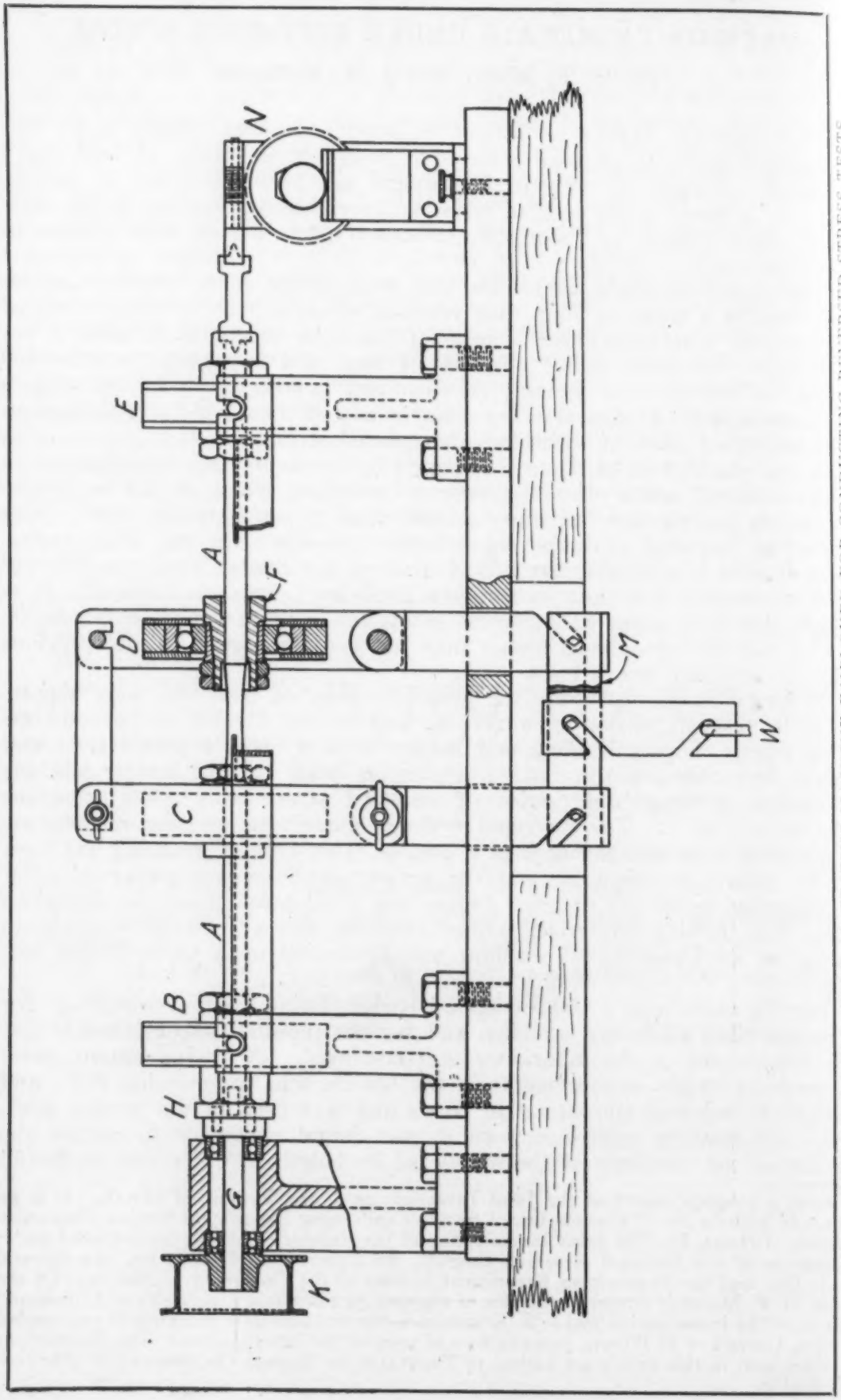


FIG. 1—ROTATING BEAM TYPE OF TESTING MACHINE EMPLOYED FOR CONDUCTING REVERSED STRESS TESTS

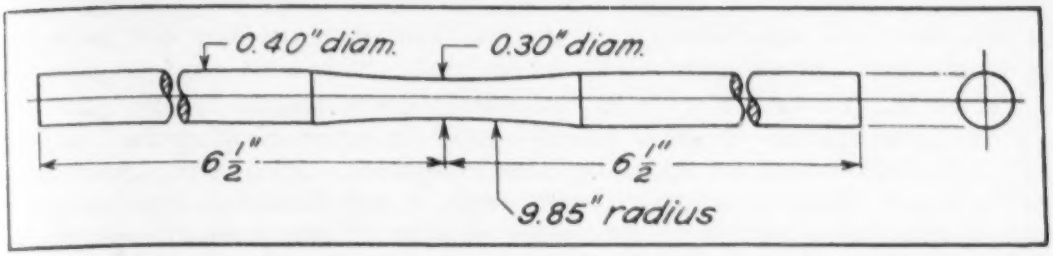


FIG. 2—SKETCH OF THE ROTATING BEAM SPECIMEN USED IN DETERMINING FATIGUE

not break at the places where the load was hung due to the localized stresses existing there. Fig. 2 shows the rotating beam specimen, which was used in the tests. To prevent variation in fatigue results due to the condition of the surface on the specimen, all fatigue specimens were finished in a standard manner, the final polish being prepared with No. 0 and No. 00 emery cloth. A system of numbering for specimens was adopted so that each specimen could be identified with respect to its position in the cross-section and in the length of the billet.

The tension, compression, and torsion tests were made by starting with an initial load and taking a reading of load and deformation, then applying an increment of deformation and taking another set of readings. The load was then reduced to the initial value and readings again taken, after which the load was increased until the extensometer showed the standard increment above the previous reading, and the load again reduced to its initial value. This procedure was continued until the yield point of the material was passed. From these data it was possible to determine the proportional elastic limit and also the elastic limit based upon permanent set.

In making the rotating beam tests a stress which would cause failure in a short time was applied to the first specimen. In successive specimens the stress was reduced until a stress was reached which the specimen could

Table I

Chemical Analysis of Steels Tested

Steel No.	Furnished by	Material furnished in	Content, per cent: Carbon	Chromium	Nickel	Silicon	Manganese	Phosphorus	Sulphur
1	Illinois Steel Co.	1 x 2-inch flats	1.20	....	....	0.19	0.25	0.021	0.021
3	John A. Roebling's Sons Co.	Billets, 4 inches square	0.52	....	....	0.24	0.56	0.037	0.029
4	John A. Roebling's Sons Co.	Billets, 4 inches square	0.37	....	....	0.16	0.58	0.032	0.035
5	Halcomb Steel Co.	1 x 2-inch flats	0.24	0.87	3.33	0.15	0.37	0.019	0.025
6	Carnegie Steel Co. through Standard Steel Co.	⅞ x 2-inch flats	0.93	....	....	0.03	0.38	0.017	0.045
7	Midvale Steel & Ordnance Co. through General Electric Co.	1 inch squares	0.41	0.18	3.41	0.25	0.75	0.020	0.020
9	American Rolling Mill Co.	1 inch rounds	0.02	....	....	0.02	0.03	0.005	0.042
10	Inland Steel Co.	⅛ inch squares	0.49	....	....	0.12	0.46	0.017	0.029
50	J. T. Ryerson & Son (Cold-drawn screw stock)	7/16 inch rounds	0.20	....	....	0.03	0.67	0.025	0.090
51	University of Illinois stock (Hot-rolled reinforcing rod)	½ inch rounds	0.18	....	....	0.06	0.37	0.013	0.039

FIG. 1—ROTATING BEAM TYPE OF TESTING MACHINE EMPLOYED FOR CONDUCTING REVERSED STRESS

withtand for 100,000,000 cycles without failures. Wherever possible these long time tests without failure were run on from three to five specimens for each of the steels investigated.

Tables III, IV and V give the principal results obtained from the various steels investigated. Figs. 3 and 4 show characteristic diagrams of test results for reversed stress tests. In these diagrams, which are plotted with logarithmic co-ordinates, values of unit stress S are plotted as ordinates and values of number of cycles of stress for rupture N are plotted as abscissas, and the diagrams are called S-N diagrams. A plotted point marked with an

Table II

Heat Treatment of Steels Tested

Steel	Structure	Heat Treatment
No. 1 1.20 carbon	Normalized	Heat to 1460 degrees Fahr.; hold 15 minutes; cool in furnace (this anneals the steel so that it can be machined); then heat to 1580 degrees Fahr.; hold 15 minutes; cool in furnace with door open.
	Sorbitic	First anneal as above; then heat to 1470 degrees Fahr.; quench in oil; reheat to 860 degrees Fahr.; hold 30 minutes; cool in air.
No. 3 0.52 carbon	Normalized	Heat to 1550 degrees Fahr.; hold 15 minutes; cool in air.
	Sorbitic	First normalize as above; then heat to 1450 degrees Fahr.; hold 15 minutes; quench in water; reheat to 1200 degrees Fahr.; cool in air.
No. 4 0.37 carbon	Normalized	Heat to 1495 degrees Fahr.; hold 15 minutes; cool in furnace with door open.
	Sorbitic, Treatments A and B	This steel was not first normalized. Heat to 1550 degrees Fahr.; hold 15 minutes; quench in water; reheat to 1050 degrees Fahr.; cool in air.
No. 5 chrome-nickel	Treatment A	Steel received annealed. Heat to 1525 degrees Fahr.; quench in oil; reheat to 700 degrees Fahr.; quench in oil.
	Treatment B	Steel received annealed. Heat to 1525 degrees Fahr.; hold for ½ hour, quench in oil. Reheat to 1450 degrees Fahr.; quench in oil. Reheat to 1200 degrees Fahr.; hold for 1 hour; cool in furnace.
	Treatment C	Steel received annealed. Heat to 1525 degrees Fahr.; hold for ½ hour, quench in oil. Reheat to 1450 degrees Fahr.; quench in oil. Reheat to 1200 degrees Fahr.; hold for 1 hour; quench in water.
No. 6 0.93 carbon	Normalized	Heat to 1600 degrees Fahr.; hold 15 minutes; cool in air.
	Pearlitic	First normalize as above; then heat to 1450 degrees Fahr.; hold 15 minutes; cool in furnace.
	Sorbitic	First normalize as above; then heat to 1450 degrees Fahr; hold 15 minutes; quench in oil; reheat to 1200 degrees Fahr.; hold 30 minutes; cool in air.
	Troostitic	First normalize as above; then heat to 1450 degrees Fahr; hold 15 minutes; quench in oil; reheat to 850 degrees Fahr.; hold 30 minutes; cool in air.
No. 7 nickel	Treatment B	Normalize by heating to 1525 degrees Fahr. and cooling in furnace; then heat to 1525 degrees Fahr.; quench in oil; reheat to 1210 degrees Fahr.; hold 2 hours; cool in furnace.
No. 9 0.02 carbon	Ferrite	Tested as received.
No. 10 0.49 carbon	Normalized	Heat to 1700 degrees Fahr.; hold 20 minutes; cool in air.
	Sorbitic	First normalize as above; then heat to 1427 degrees Fahr.; quench in water; reheat to 1200 degrees Fahr.; cool in furnace.
No. 50 Cold-drawn	As received	
	Annealed	Heated to 1300 degrees Fahr.; hold for 15 minutes; cool in furnace.
	Annealed	Heated to 1550 degrees Fahr.; hold for 15 minutes; cool in furnace.
No. 51 Hot-rolled	As received	
	Cold stretched	Reduced to diameter of 0.44-inch; then heated to 500 degrees Fahr.; cool in furnace.
	Cold stretched	Reduced to diameter of 0.48-inch; then heated to 500 degrees Fahr.; cool in furnace.
	Cold bent	Bent to an angle of 45 degrees at the middle, straightened cold.

arrow indicates that the specimen was not broken at the end of the test. Altogether 963 reversed stress tests were made; 10 different steels were tested, with various heat treatments, numbering 23 in all. For each treatment of each steel the test results were plotted as an *S-N* diagram.

The *S-N* diagram given in Figs. 3 and 4 indicate that up to some value of *N* the results of the reversed stress tests may be well represented by a sloping straight line, and that at this critical point on the *S-N* diagram there is a decided break, and for higher values of *N* a horizontal straight line seems to represent the relation between *S* and *N*, up to a value of *N* of

Table III
Results of Tension Tests

Steel	Tension: Proportional elastic limit, Pounds per square inch	Tension: Yield point, Pounds per square inch	Tension: Ultimate, Pounds per square inch	Tension: Per cent of elongation	Tension: Per cent of reduction of area	Endurance limit Rotating beam machine, Pounds per square inch
0.02 carbon—As received	16,100	19,000	42,400	48.3	76.2	26,000
Hot rolled—As received	38,200	40,300	61,500	41.0	66.7	28,000
Hot rolled—Reduced to 0.48-inch	60,000	63,300	67,600	22.3	63.3	35,000
Hot rolled—Reduced to 0.44-inch	69,600	None	73,400	14.2	59.5	41,000
Hot rolled—Bent cold and straightened	.....	.....	.....	....	....	30,000
Cold drawn—As received	55,200	None	86,800	13.8	49.3	41,000
Cold drawn—Annealed at 1300 degrees Fahr.	26,700	29,500	56,600	41.3	65.5	29,000
Cold drawn—Annealed at 1550 degrees Fahr.	28,000	30,000	57,700	40.8	63.2	25,000
0.37 carbon normalized	34,500	34,900	71,900	29.4	53.5	33,000
0.37 carbon sorbitic—Treatment A	80,600	87,300	102,600	23.3	65.1	57,000
0.37 carbon sorbitic—Treatment B	61,500	63,100	94,200	25.0	63.0	45,000
0.49 carbon sorbitic	67,700	69,700	96,900	23.5	57.8	48,000
0.52 carbon normalized	45,400	47,600	98,000	24.4	41.7	42,000
0.52 carbon sorbitic	80,300	84,300	111,400	21.9	56.6	55,000
0.93 carbon pearlitic	28,000	33,400	84,100	24.8	37.2	30,500
0.93 carbon sorbitic	60,300	67,600	115,000	23.0	39.6	56,000
0.93 carbon troostitic	97,200	None	188,300	9.9	29.3	98,000
1.20 carbon normalized	58,600	60,700	116,900	7.9	11.6	50,000
1.20 carbon sorbitic	120,400	130,100	179,900	9.0	15.2	92,000
3½ nickel—Treatment B	82,400	91,100	111,800	23.6	60.2	63,000
Chrome-nickel—Treatment A	115,500	128,100	138,700	18.2	61.8	68,000
Chrome-nickel—Treatment B	101,700	103,700	113,300	24.2	68.7	65,000
Chrome-nickel—Treatment C	86,200	100,500	114,200	23.2	69.3	67,000

Table IV
Results of Compression and Torsion Tests

Steel	Compression: Proportional elastic limit, Pounds per square inch	Compression: Yield point, Pounds per square inch	Compression: Ultimate Pounds per square inch	Torsion: Proportional elastic limit, Pounds per square inch	Torsion: Yield point, Pounds per square inch	Modulus of elasticity
0.02 carbon—As received	19,200	20,600	31,200	12,500	13,600	11,770,000
0.37 carbon normalized	36,300	38,100	59,200	20,300	22,500	11,790,000
0.37 carbon sorbitic—Treatment A	75,800	84,500	102,800	51,600	60,200	11,960,000
0.49 carbon sorbitic	55,900	60,100	76,500	36,800	None	12,150,000
0.52 carbon normalized	47,800	51,000	78,700	30,000	34,600	11,720,000
0.52 carbon sorbitic	84,400	87,400	97,800	52,200	None	12,115,000
0.93 carbon pearlitic	23,500	29,700	69,200	15,600	22,500	11,880,000
0.93 carbon sorbitic	64,800	72,700	97,100	42,000	None	12,130,000
0.93 carbon troostitic	106,500	None	.....	75,200	None	11,960,000
1.20 carbon normalized	55,300	57,900	96,500	36,500	39,700	11,700,000
1.20 carbon sorbitic	102,700	111,500	149,200	80,600	None	11,940,000
3½ nickel—Treatment B	86,400	94,000	95,100	55,500	None	11,890,000
Chrome-nickel—Treatment A	122,600	130,100	133,000	72,400	84,900	11,510,000
Chrome-nickel—Treatment B	97,800	100,000	100,300	62,500	None	11,980,000
Chrome-nickel—Treatment C	91,500	97,400	99,900	62,300	None	12,020,000

100,000,000 cycles of stress, with no indication of a further break in the diagram. This critical point was a characteristic of the *S-N* diagrams for all steels tested. So far as can be seen from test results, for a value of *S* lower than the critical value corresponding to this break in the *S-N* diagram, the material would withstand an indefinite number of reversals of stress.

It is, of course, possible that the relation between *S* and *N* is of such a

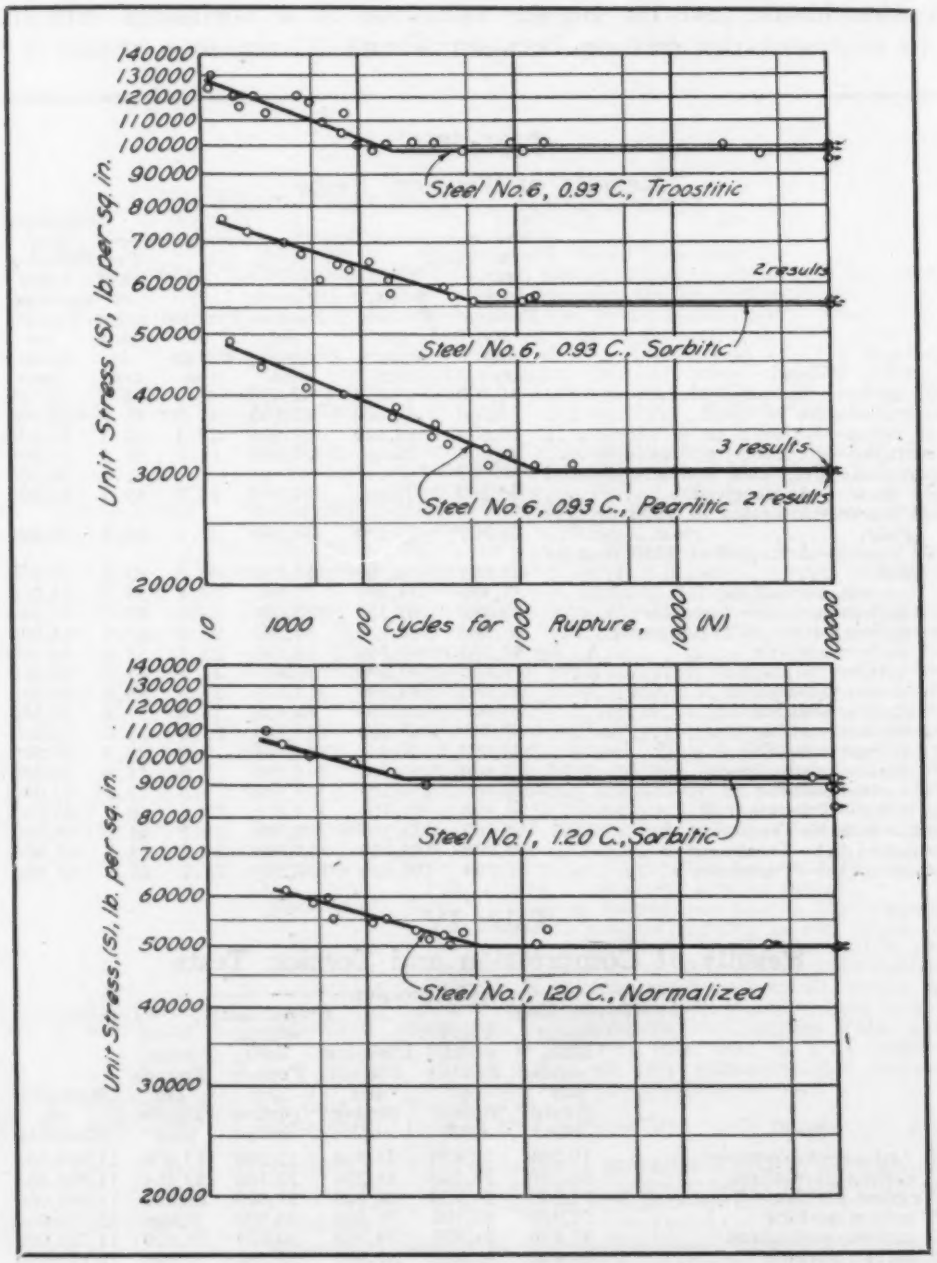


FIG. 3—TWO CHARACTERISTIC CURVES PLOTTED FROM RESULTS OF REVERSED STRESS TESTS. LOGARITHMIC SCALES HAVE BEEN USED FOR CONVENIENCE

nature that for some value of *N* beyond 100,000,000 the *S-N* diagram again slopes downward, or that for values of *N* greater than 100,000,000 the *S-N* diagram is a line with a very slight downward slope rather than an ab-

solute horizontal line. However, in view of the fairly sharp break shown in the diagram, and of the range and number of tests made, it is believed that the unit stress S corresponding to the horizontal part of an S-N diagram for steel may be regarded as a limit below which an indefinite number of reversals of stress will not cause failure. To this limiting stress the name *endurance limit* has been given. It should be noted that for all the steels

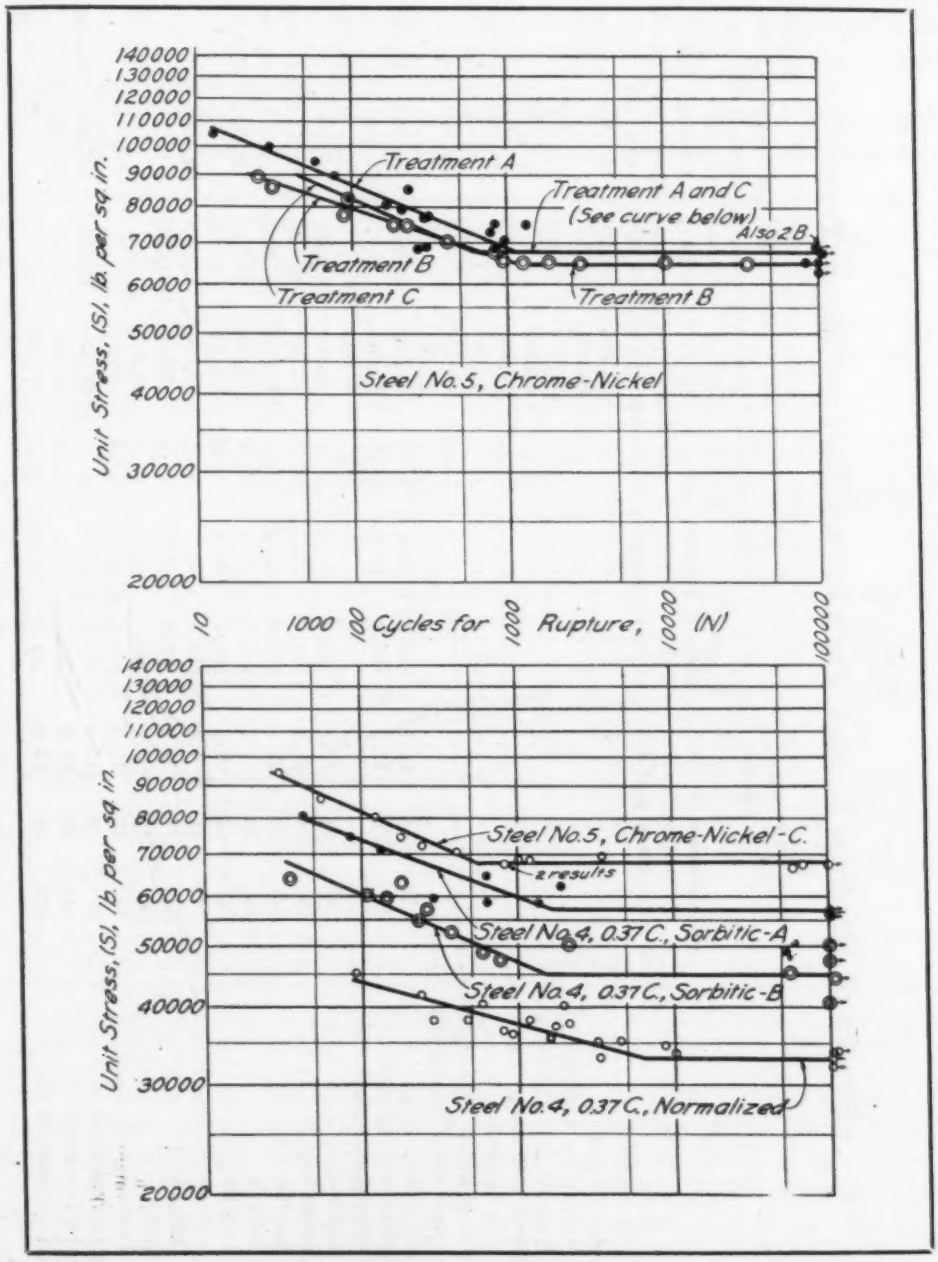


FIG. 4—TWO MORE CHARACTERISTIC CURVES PLOTTED FROM RESULTS OF REVERSED STRESS TESTS. LOGARITHMIC SCALES HAVE BEEN USED FOR CONVENIENCE

tested the endurance limit was developed at a value of N less than 10,000,000. It is believed that the series of reversed stress tests made in this investigation furnish a clearer demonstration of the existence and magnitude of an en-

Table V

Results of Hardness Impact, Francke and Reversed Stress Tests

Steel	Hardness		Impact Bending Energy of rupture foot pounds	Impact Tension			Endurance Limits			Francke bending FR Point in Francke test	Repeated impact Number of double blows
	Brinell	Sclero-scope		Energy of rupture foot pounds	Per cent of elongation	Per cent of reduction of area	Farmer rotating beam, Pounds per square inch	Upton-Lewis reversed bending, Pounds per square inch	Olsen-Foster reversed torsion, Pounds per square inch		
0.02 carbon—As received	69	18	19.3	84.9	27.0	72.7	26,000	23,000	12,500	.....	260
Hot rolled—As received	..	..	....	....	....	....	28,000	.....	.....	.....	242
Hot rolled—Reduced to 0.48-inch	..	..	....	....	....	....	35,000	.....	.....	.....	280
Hot rolled—Reduced to 0.44-inch	..	..	....	....	....	....	41,000	.....	.....	.....	361
Hot rolled—Bent cold and straightened	..	..	....	....	....	....	30,000	.....	.....	.....	...
Cold drawn—As received	..	..	....	....	....	....	41,000	.....	.....	.....	316
Cold drawn—Annealed at 1300 degrees Fahr.	..	..	....	....	....	....	29,000	.....	.....	.....	202
Cold drawn—Annealed at 1550 degrees Fahr.	..	..	....	....	....	....	25,000	.....	.....	.....	223
0.37 carbon normalized	132	18	15.8	168.4	32.4	52.7	33,000	30,000	16,000	33,000	183
0.37 carbon sorbitic—Treatment A	209	26	53.2	163.2	24.0	62.8	57,000	.....	32,500	.....	550
0.37 carbon sorbitic—Treatment B	..	..	....	....	....	....	45,000	.....	.....	44,000	503
0.49 carbon sorbitic	197	23	22.5	152.3	24.0	55.1	48,000	39,000	26,000	.....	319
0.52 carbon normalized	193	24	13.2	188.5	24.2	45.6	42,000	32,000	.....	39,500	275
0.52 carbon sorbitic	227	30	21.4	172.0	22.2	55.1	55,000	44,000	.....	66,000	486
0.93 carbon pearlitic	162	23	2.2	141.3	21.2	34.5	30,500	28,500	16,300	34,000	66
0.93 carbon sorbitic	227	31	3.3	193.2	21.6	43.9	56,000	44,000	.....	.....	128
0.93 carbon troostitic	380	51	4.4	186.8	15.0	41.3	98,000	.....	52,000	.....	227
1.20 carbon normalized	224	31	1.9	88.8	8.8	14.6	50,000	45,000	.....	.....	39
1.20 carbon sorbitic	369	45	2.0	109.1	6.3	11.0	92,000	.....	.....	.....	172
3½ nickel—Treatment B	242	28	41.0	179.9	22.8	57.4	63,000	.....	.....	.....	524
Chrome-nickel—Treatment A	291	36	45.4	173.8	17.0	61.7	68,000	52,000	37,000	62,000	1073
Chrome-nickel—Treatment B	247	28	53.8	175.3	22.2	63.2	65,000	.....	31,500	.....	714
Chrome-nickel—Treatment C	246	29	56.0	187.6	23.4	67.0	67,000	.....	.....	.....	722

durance limit than has been furnished by any previous tests made on this subject.

Fig. 5 has been drawn to show the relation between the endurance limit, the proportional elastic limit, and the tensile ultimate strength. The endurance limit as determined by the temperature test is also shown and is discussed later. These curves make clear that the proportional elastic limit cannot be used as a criterion of fatigue strength. The ultimate strength is a somewhat better criterion than the proportional elastic limit. It will be noted that, in general, the proportional elastic limit and the ultimate strength both increased as the endurance limit increases.

It should be noted that the determination of the elastic limit and the ultimate strength depends upon the average properties of a considerable mass

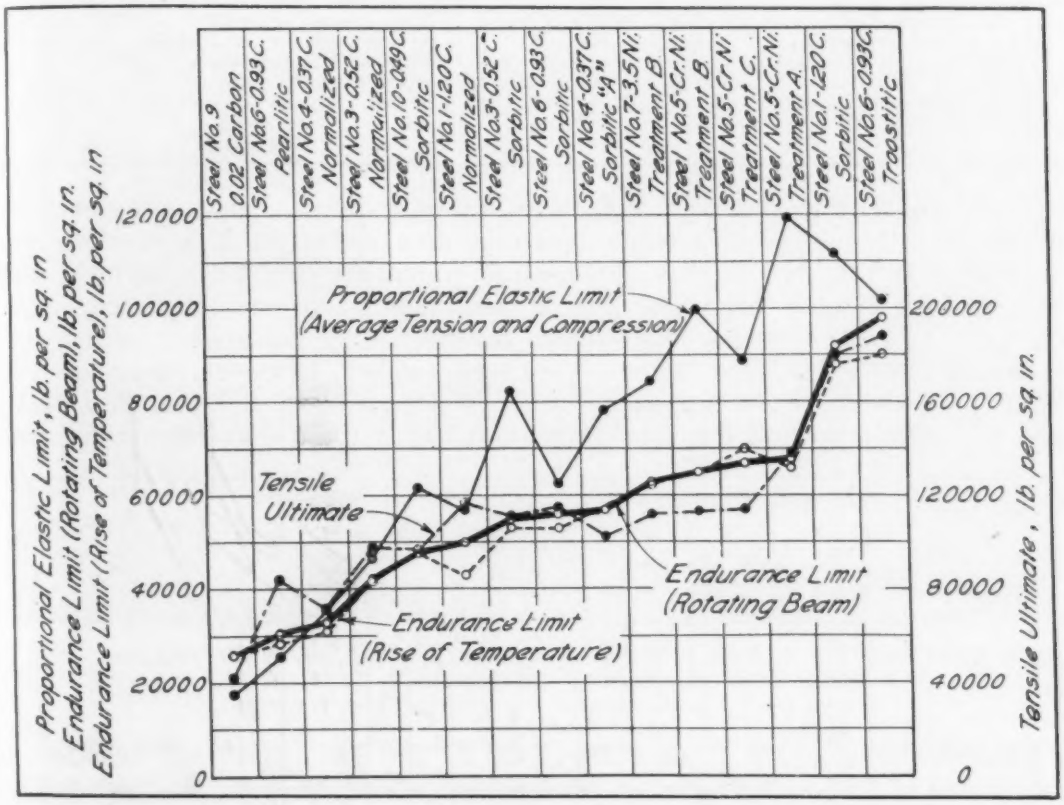


FIG. 5—CURVES SHOWING RELATION BETWEEN ENDURANCE LIMIT, PROPORTIONAL ELASTIC LIMIT, AND TENSILE ULTIMATE STRENGTH

of material. A minute defect, such as a nick on the surface, an incipient crack in the structure, or a localized stress resulting from heat treatment, will not in general affect the determination of the elastic limit to an appreciable extent. On the other hand, such a localized effect may readily act as a nucleus for structural damage which spreads under repeated stress in the form of minute cracks, with continued localized stress present at the roots of these cracks, and finally causes failure.

By reference to Table III it is seen that in none of the steels did the endurance limit under completely reversed stress fall below 36 per cent of the ultimate tensile strength; in only one metal did the endurance limit fall below 40 per cent of the ultimate tensile strength, while for several metals the endurance limit was more than 50 per cent of the ultimate tensile strength. In this connection it should be noted that the steels tested were to a high

Table VI

Endurance Limit Tests Are Compared

No.	Steel	Endurance limit, pounds per square inch—Rotating beam test	Rise of temperature test
1	1.20 carbon normalized.	50,000	43,000
	Sorbitic	92,000	88,000
3	0.52 carbon normalized.	42,000	41,500
	Sorbitic	55,000	53,000
4	0.37 carbon normalized.	33,000	31,000
	Sorbitic—Treatment B.	45,000	49,000
5	Chrome-nickel—Treatment A	68,000	66,000
	Treatment B	65,000	65,000
	Treatment C	67,000	70,000
6	0.93 carbon pearlitic...	30,500	28,500
	Sorbitic	56,000	53,000
	Troostitic	98,000	90,000
7	3.5 nickel—Treatment B	63,000	62,500
9	0.02 carbon—As received	26,000	26,000
10	0.49 carbon sorbitic....	48,000	48,000
50	Cold drawn—As received	41,000	41,500
	Annealed at 1300 degrees Fahr.	29,000	27,500
51	Hot rolled, 0.18 carbon —As received	28,000	27,000
	Reduced to 0.48-inch...	35,000	38,500
	Reduced to 0.44-inch...	41,000	40,500
9	0.02 carbon, tested on Olsen-Foster reversed torsion machine	12,500	13,000
	Tested on Upton-Lewis reversed bending machine	23,000	27,000

degree free from inclusions and other internal defects, that the specimens had no abrupt changes of outline, and that they had a good surface finish.

Fig. 6 shows the relation between the endurance limits and Brinell hardness, Charpy impact bending, Charpy impact tension, and repeated impact results. It is evident that the impact results cannot be used as a criterion of fatigue strength. The Brinell hardness number, however, shows a consistent relation to the endurance limit. It is not clear why this should be the case, and the writers offer no explanation other than that of an empirical

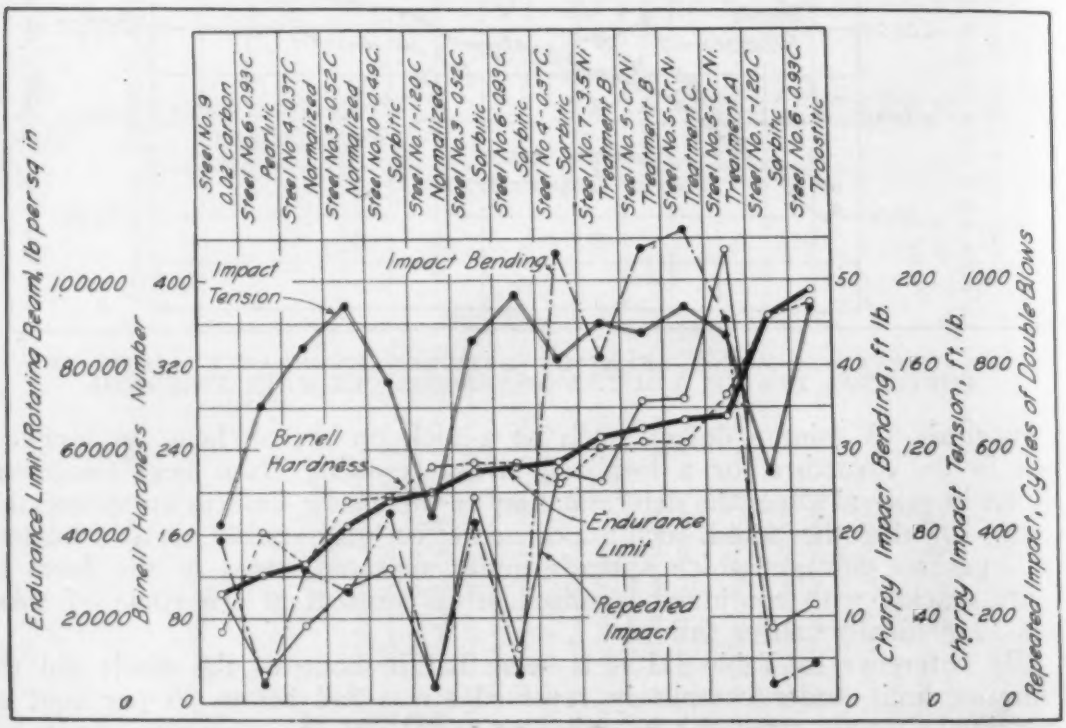


FIG. 6—CURVES SHOWING RELATION BETWEEN ENDURANCE LIMIT, BRINELL HARDNESS, IMPACT BENDING, IMPACT TENSION AND REPEATED IMPACT RESULTS

relation. The rise of temperature test described in the next paragraph, is a short time test for endurance strength which gives more accurate results than does the Brinell test, and which seems to have a rather more logical basis.

It was found that the endurance limit for the steels tested could be predicted with a good degree of accuracy by the measurement of rise of temperature under reversed stress applied for a period of a few minutes or less.

This action is explicable in view of the intercrystalline and intracrystalline slippage under repeated stress, which is shown by the miscroscope.

The apparatus used in making the temperature test is shown in Fig. 7. The machine used was designed to test the regular 13-inch, rotating beam specimen, Fig 2, and to produce the same type of stress as that produced in the rotating beam machine used for the main series of tests described in

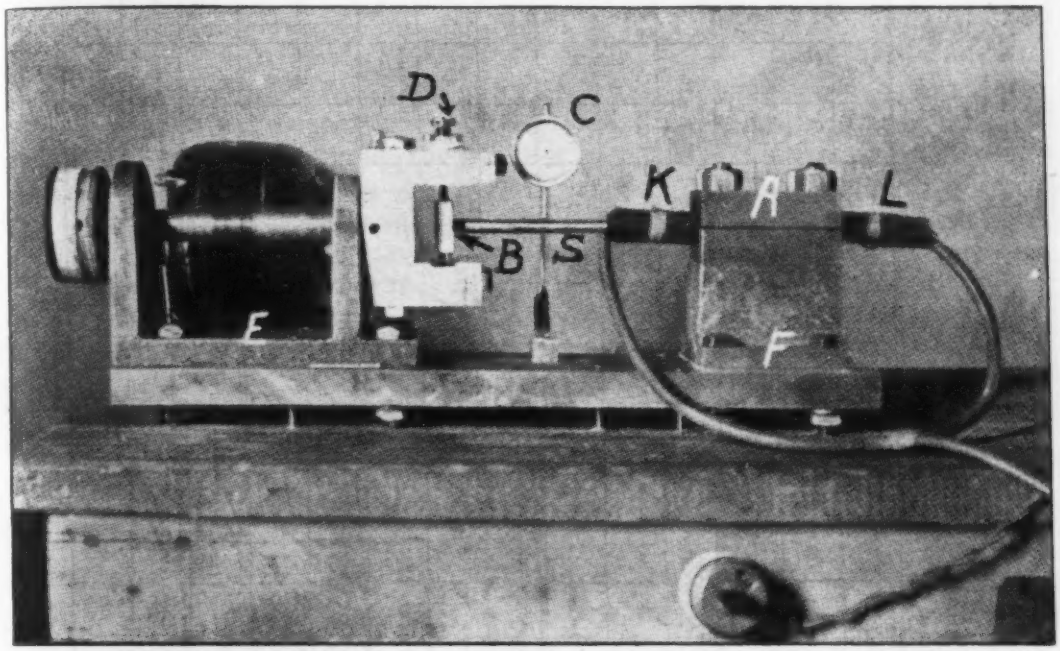


FIG. 7—TEMPERATURE TEST APPARATUS WHICH HAS BEEN DEVISED FOR PREDICTING ENDURANCE LIMITS OF SPECIMENS

this article. As shown in Fig. 7, the specimen *S* is held horizontally in V-shaped grips, *A*. The load is applied on a ball bearing, *B*, at the end of the specimen, the bearing being heat insulated from the specimen by a fiber collar 1/16-inch thick. The machine is also heat insulated from the base at points *E* and *F*, to prevent heat traveling from the bearings through the base to the specimen. The load on the specimen is measured by reading the deflection of the dial *C*, a load-deflection curve for the specimen having been previously obtained by recording a set of loads and corresponding deflection readings. The load can be varied by an adjusting screw *D*, in the head of the machine. A thermocouple cannot be attached readily to a rotating specimen, and it will be noted that the machine is so designed that the specimen does not turn, but that the head of the machine rotates. The left-hand end of the specimen is thus moved in a circle concentric with its axis, the radius of the circle being the deflection corresponding to the desired stress.

Differential copper-constantan thermocouples were used to measure the rise of temperature. One couple was attached at the section of greatest stress *K*, and was held directly against the specimen by means of tape. The other

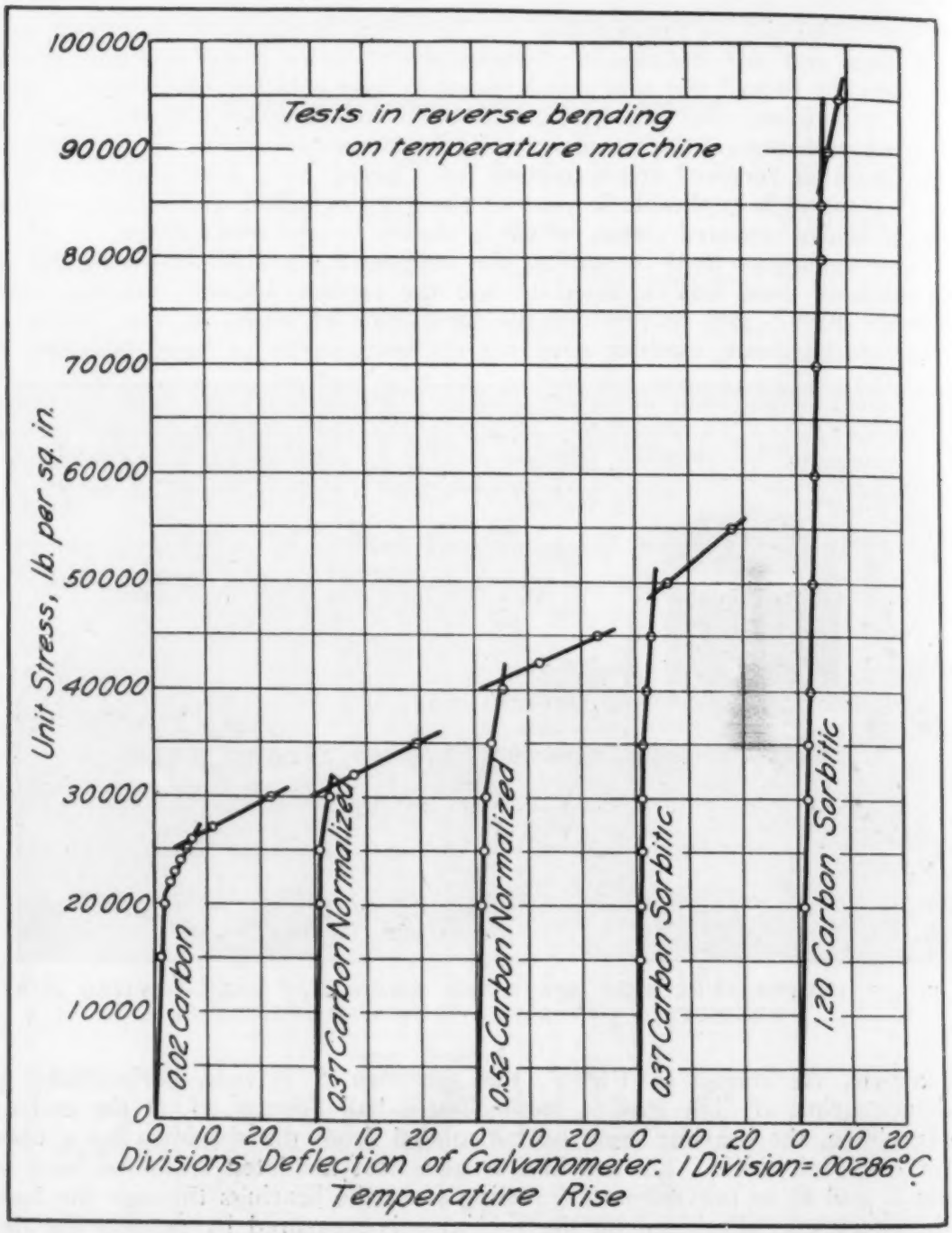


FIG. 8—TYPICAL CURVES SHOWING INCREASE IN TEMPERATURE WITH INCREASED STRESS

couple was at *L*, a section of zero stress, and was separated from the specimen by a single layer of thin paper. The couples were connected in series and the free wires lead to a galvanometer. When the couples were at the same temperature no deflection of the galvanometer was shown but when the temperature became different a corresponding deflection occurred.

The temperature test finally adopted as a standard consists in running the machine at a speed of 1000 revolutions per minute for 30 seconds, using a known stress and recording the maximum deflection of the galvanometer.

Then with a series of such readings, corresponding to a series stresses, a curve is plotted to show the increase in temperature with increase of stress. The point at which the curve shows a sharp break corresponds to the endurance limit. Typical curves are shown in Fig. 8. In the cases of sorbitic structures in plain carbon steel and in that of alloy steels it was found necessary to increase the time of the run at each stress, from 30 seconds to 2 minutes, since these materials are slower in heating under stress.

A reference to Table VI and Fig. 5 shows a very good degree of coincidence between the values of endurance limit determined by the temperature test and those values determined by long time rotating beam tests. The temperature test was suggested and to some extent used by C. E. Stromeyer, Manchester, England, as long ago as 1913. He did not have the opportunity, however, of carrying out a sufficient number of long time tests to establish thoroughly the temperature limit as identical with the endurance limit under repeated stress.

It should be stated that the credit of developing the temperature test in connection with the present investigation should be given to J. W. Harsch, a member of the test party of the present investigation, and to Prof. W. J. Putnam of the department of theoretical and applied mechanics of the University of Illinois..

Previous investigators have shown that the shape of the specimen may exert a great influence on the endurance strength of the material. Square shoulders and sharp notches are known to reduce the endurance limit as much as 50 per cent. A study of this matter was first made in this investigation on a 0.49 per cent carbon sorbitic steel. It was found that specimens which had their diameter reduced by a radius of 1 inch were almost as strong as those in which a radius of 9.85 inch was used. A 1/4-inch radius reduced the strength about 8 per cent, square shoulders reduced the strength about 51 per cent, and a V-notch reduced the strength about 60 per cent. Square shoulders and a 1/4-inch radius showed about the same effect on a soft 0.02 per cent carbon steel as they did with the harder steel first mentioned.

It has been known that the condition of the surface of a specimen may exert a marked influence on the fatigue strength of steel. A study of this matter was first made on a 0.49 per cent sorbitic steel carbon. One series of specimens was finished carefully in order to remove all scratches and was finally given a high rouge polish. It was found that these specimens were only slightly stronger than those finished with the standard finish. Specimens with a ground finish were slightly weaker than those with the rouge finish, smooth turned still weaker, and rough turned weaker even than the smooth turned. The rough turned specimens were about 18 per cent lower in endurance limit than those finished with the rouge polish.. Similar results on the smooth turned and rough turned specimens were found with a soft 0.02 per cent carbon steel.

To determine whether stressing a specimen above its normal endurance limit would have a serious effect on the endurance limit under subsequent stresses, a number of different combinations of overstresses and cycles of rupture were tried on a 0.49 per cent sorbitic steel carbon. For instance, one series of specimens was given 5000 cycles of stress at a unit stress 10 per cent higher than its normal endurance limit. These specimens were then tested in the usual way to determine whether the overstressing had changed the endurance limit. It was found that 10 per cent and 20 per cent of the overstress applied 5000 times, 29 per cent of overstress applied 1000 times, and 38 per cent of overstress applied 100 times did not reduce the endurance limit

appreciably. On the other hand, 35 per cent of overstress applied 1000 times reduced the endurance limit about 4 per cent, and 29 per cent of overstress applied 5000 times reduced the endurance limit 11 per cent. It is evident therefore that a material may be able to withstand a considerable amount of overstress if the overstress is applied only a comparatively small number of times. Tests on a hard, high carbon steel gave similar results to those above mentioned, the percentage of reduction being somewhat higher than for the soft steel.

It is a well known fact that the effect of subjecting steel to a tensile stress beyond the yield point is to raise the static elastic strength to a marked degree, as is illustrated by the strength of cold-drawn and cold-rolled steel. It was found in the case of a 0.18 per cent carbon steel that the effect of such cold work was less marked on the endurance limit than on the static elastic strength, though some increase of endurance limit was observed after cold working. Annealing of commercial cold-drawn screw stock was found to reduce its endurance limit.

Figs. 3 and 4 illustrate the effect of heat treatment on the endurance limit. In the soft condition of the pearlitic structure of the 0.93 per cent carbon steel the material has an endurance limit of 30,000 pounds per square inch. This can be increased by 84 per cent if the steel is given a sorbitic structure by heat treatment, and by 221 per cent when it is given a troostitic structure. In general, a heat treatment which raises the static elastic strength and the ultimate tensile strength raises the endurance limit also, but the increase in static strength is not a reliable indicator of the amount of increase in endurance limit.

In those cases in which the same steel was tested in a hard and a soft condition the results show that giving the material a sorbitic structure by heat treatment may greatly increase the endurance limit without much sacrifice of ductility. The results thus far obtained on eight different steels in reversed torsion indicate that the ratio of the endurance limit in torsion to the endurance limit in bending is about 0.52.

With one soft steel it was found that the computed stress at the endurance limit in bending was actually about 33 per cent higher than the proportional elastic limit in tension. This material was almost pure ferrite and the result indicates that homogeneity of structure is a valuable factor in giving a high resistance against fatigue. Results indicate that thorough annealing also tends to produce a condition which will give a high ratio of endurance limit to proportional elastic limit. It should be noted that it is quite possible for a steel to have a high ratio of endurance limit to proportional limit, when both values of endurance and proportional limit are low. Only one nickel and one chrome-nickel steel were investigated. The results indicate that the alloy steels have somewhat higher endurance limits for the same ductility, as compared with plain carbon steels.

One theory of the nature of the fatigue of metals is the crystallization theory. Often materials which have failed under repeated stress show a crystalline fracture, and this theory supposed that under the action of repeated stresses the internal structure of a metal changed from fibrous to crystalline, and that different metals varied in their resistance to this change.

The use of the microscope in examining the structure of metals has discredited this theory. All metals are seen to be of a crystalline structure under all service conditions, and no evidence of appreciable change of structure can be observed in a metal subjected to repeated stress. There does appear to be a breaking down of crystals as indicated by the formation of

minute cracks or slip bands extending across the crystal. The crystallization theory of failure under repeated stress practically has been abandoned today.

A second theory of failure of metals under repeated stress was that advanced by the distinguished German investigator, Bauschinger. His theory holds that under stress varying from zero to a maximum, it is possible for metals to acquire new elastic limits which may be anywhere between the original proportional elastic limit and the yield point, and may in some cases even exceed the yield point. These new elastic limits, or natural elastic limits, as Bauschinger called them, depend upon the number of cycles of stress to which the material is subjected, being higher for the greater number of cycles. For stresses within the natural elastic limit the metal is assumed to possess indefinite endurance. Bauschinger's theory does not imply a change in the crystalline structure of the material, but does imply some change in the inherent nature of the material.

A third theory has been suggested by various investigators and was formulated by the writers, who later found that it had been elaborated by Gilchrist. This theory may be stated briefly as follows: Fracture in fatigue is caused by the statical breaking limit being exceeded at one point only, from which, when once started, rupture spreads. The raising of the stress at the point where fracture commences is due to an irregularity of the bar, which may be an irregularity or discontinuity in the metal, either on the surface or in the body of the bar.

This theory may be called the theory of nonhomogeneity or of localized stress. The effect of external nonhomogeneity due to scratches, tool marks, square shoulders, and notches is well known. Internal nonhomogeneity may be due to blow holes, pipes, inclusion of slag, irregularities of crystalline structure on account of the presence of two or more constituents of varying strength, variation in orientation of crystals, or it may be due to the presence of initial stresses caused by mechanical working or by heat treatment. This localized stress produces no appreciable effect under a single load, owing to the minute area over which it exists, but under load repeated many times, there is started from this area a microscopic crack at the root of which high localized stress exists and which, under repetitions of stress, spreads, finally causing failure.

The writers do not look upon these fatigue failures as being due necessarily to accidental flaws or irregularities. In practice they may often be due to such causes, but the uniformity of the results in the present tests points to the conclusion that the endurance limit is a property of the material just as much as the ultimate strength is. If in these tests the failure is due to flaws, then it is believed that these flaws are an inherent part of the structure of the particular steel which is being tested..

The following subjects are suggested for further investigation: The effect of repetition of stress not reversed; tests on other ferrous metals not covered in this investigation, especially various alloy steels; tests on nonferrous metals; detailed study of effect of heat treatment; tests in direct tension-compression; more complete study of reversed torsion; study of the mechanism of fatigue failure as revealed by the microscope; effect of repeated understressing; strength of cast metal under repeated stress and repair by heat treatment of structural damage due to repeated stress.

RECLAIMING HIGH CARBON GEARS

By R. L. Dowdell

FOR several years a tractor company has been practically scrapping a large number of splined jack-shaft gears. In Fig. 1 is shown one of these gears at about half size. Failure in service occurred in two ways. (1), By the stripping of the gear teeth; and (2), by the shearing of the spline at the base of the gear as indicated by the arrow in Fig. 1. With ordinary hardening and drawing operations these gears were made so brittle that they would fracture when tapped with a hammer, thus naturally all service tests on them failed. Specifications on the gears called for approximately 1.5 per cent chromium and 0.20 per cent carbon. They were to be carburized in a cyanide bath for a depth of 1/16 inch. In the heat treated or finished state the scleroscope hardness should fall between 85 and 95.

Microscopic examination of sections taken at right angles to the main axis through some of the gears which had failed, showed that they had a great depth of hardening. In fact a large number of them were found

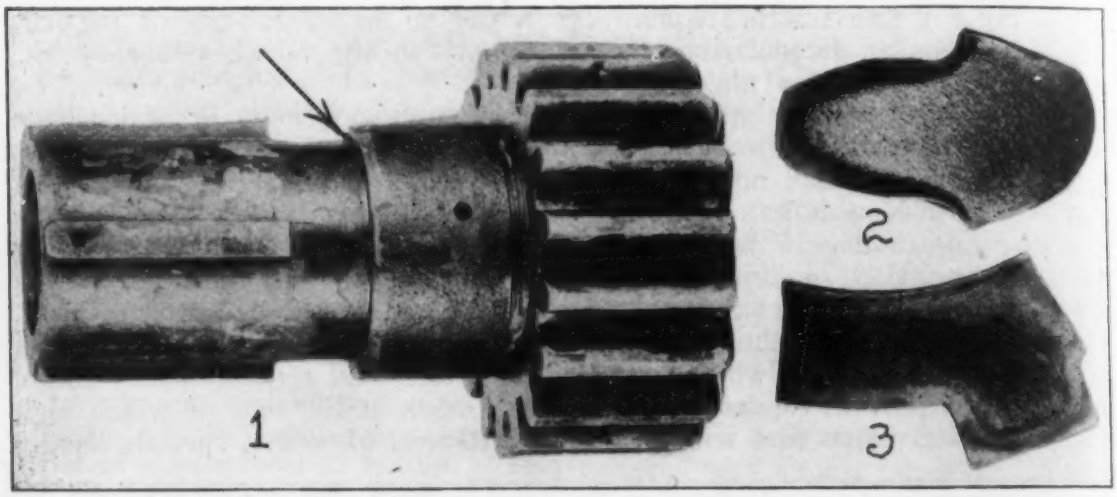


Fig. 1—One of the splined jack-shaft gears. About one-half actual size. Fig. 2—Cross section of gear tooth drawn at 200 degrees Cent. for 1 hour. X 2. Fig. 3—Cross section of spline drawn at 200 degrees Cent. for 1 hour. X 2. Both Figs. 2 and 3 show a martensite case with troostite at a depth of about 1 millimeter. See Figs. 7 and 8.

to be martensitic even in the centers of the largest sections. The grain size indicated that these gears had not been overheated thus the depth of hardening must have been due to some other influence. Several of these gears were normalized in order to change them into the pearlitic condition and observed on the microscope. This examination showed that they had been carburized completely to the center and instead of being 0.20 per cent carbon were found to be 0.75 per cent carbon. In Figs. 4 and 5 are shown the microstructure at the extreme edge and at the center respectively of one of these normalized gears.

As the decarburization of the gears by thermal means was impracticable, it was believed that these gears could be reclaimed by a heat treatment which would give them a tough core with a hard case by varying the internal structures without altering the carbon content. With this idea in mind

A paper presented by title at the Indianapolis Convention. The author, R. L. Dowdell, is instructor in metallography, University of Minnesota, St. Paul, Minn.

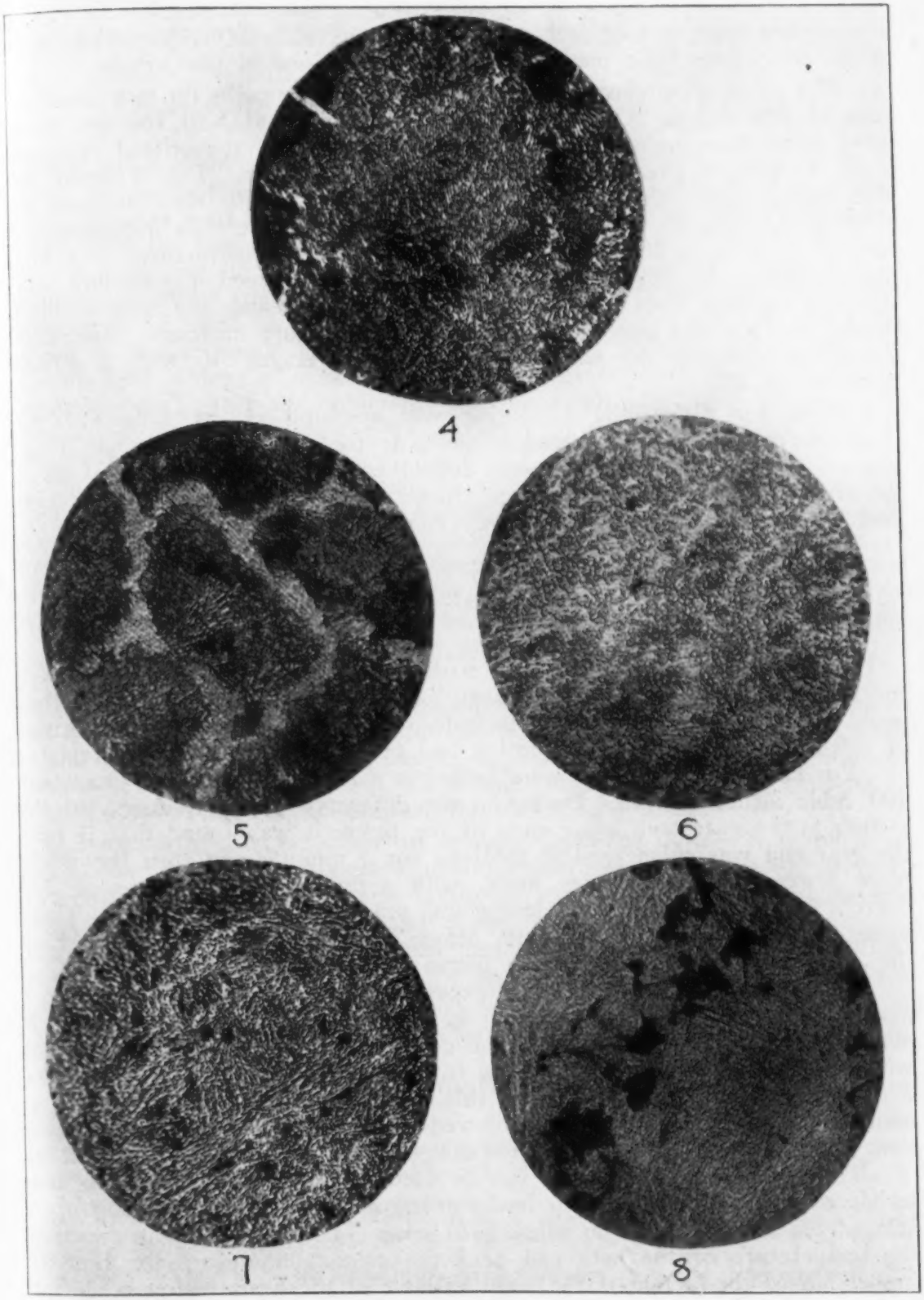


Fig. 4—Laminated pearlitic microstructure at extreme edge of normalized gear. Etched in picric acid. X 800. Fig. 5—Dark area shows laminated pearlite and light area shows ferrite at center of normalized gear. Etched in picric acid. X 800. Fig. 6—Granular pearlitic structure of annealed gear. Etched in picric acid. X 800. Fig. 7—Martensitic structure in case of gear drawn at 200 degrees Cent. for 1 hour. Etched in picric acid. X 800. Fig. 8—Light area shows martensite and dark area shows troostite at depth of 1 millimeter in gear drawn at 200 degrees Cent. for 1 hour. Etched with picric acid. X 800.

a treatment was devised and was found to be successful in making these gears serviceable. The method employed is outlined in this article.

The gears were charged into a cold furnace, brought up to a temperature of 770 degrees Cent. (1418 degrees Fahr.) and held for one hour. They were then cooled as slowly as possible through the critical range in order to form a granular pearlite throughout the gear. Fig. 6 shows the structure of these annealed gears. This granular pearlitic structure was desired in the core for two reasons: (1), Because of the high impact toughness of granular pearlite as compared with other microstructures in a high carbon steel; (2), when granular pearlite is once formed it goes into solution more slowly than other microstructures, lengthening the time required in the lead pot and tending to make the results more uniform. After this annealing operation the scleroscope hardness averaged 46 with a Brinell hardness of 212.

Packing for differential hardening was accomplished as follows: (A). Asbestos cord was laced between the gear teeth and tied around abrupt changes in section to avoid notch difficulties; and (B). Instead of using asbestos cord, a clay mixture was found to be satisfactory for keeping some of the areas soft. The mixture consisted of:

	Per cent
Fireclay	66
Water glass ($Na_2 SiO_3$)	20
Salt (NaCl)	7
Fibrous hardening compound	7
	100

The above was mixed with water so that it was just thin enough to stick to the steel surface to be kept soft. After the parts were clayed they could be dried at practically any rate of heating between temperatures of 100 and 200 degrees Cent. until it had set about as hard as concrete.

For hardening, the gears were heated in a lead pot containing practically 100 cubic inches of lead. Owing to the difference in the thickness of the section at the gear and spline ends of the piece, it was found that if only the gear end was submerged in the lead for 5 minutes and then the whole piece lowered for 4 minutes more, with a finishing temperature of 770 degrees Cent.; the depth of hardening was practically 1/16 inch deep. These pieces were quenched in a medium heavy quenching oil. After quenching the clay was broken off and the pieces drawn.

The gears were drawn at 200 degrees Cent. for one hour. Fig. 2 shows a section through a gear tooth and Fig. 3 a section through the spline at a magnification of two diameters. The case is of martensite at the outside while about one millimeter further in troostite appears as is shown by Figs. 7 and 8 respectively. The core in this differential hardening operation remained unchanged as it was not allowed to go above the Ac transformation. The scleroscope hardness of the case after these operations averaged 90.

This type of heat treatment can be used successfully in reclaiming materials of similar nature which have undergone expensive machining operations thus making them too valuable to scrap. If large lead pots are used, the temperature of the bath can be kept constant, therefore the time of immersion of the section is the main variable in the heat treatment. An air bath type of furnace would probably be unsatisfactory for this type of treatment. Uniform sections can be treated more easily than sections with variable dimensions. Most of the work in this investigation was performed by a group of engineering students of whom A. R. Kleinschmidt deserves the most honorable mention.

OCCURRENCE OF OXIDES AND NITRIDES IN BOILER TUBE STEEL

By A. E. White and J. S. Vanick

THE influence of the solid compounds of oxygen and nitrogen, such as the oxides and nitrides, upon the properties of metals has of late been receiving some well deserved attention. Most of the work has been concentrated upon the nitrogenization of steel by ammonia and the study of compounds occurring in fusion welds. Recent progress in the study of ammonia nitrogenized iron and electric arc welds[1] has indicated the presence of compounds of nitrogen in these materials. In addition the occurrence of oxides in fusion welds has demanded attention. Perhaps an equally important field which is occasionally touched upon, involves the study of the origin and mode of occurrence of the solid compounds of gases in metals and the relation of these compounds to the structure and physical properties.

In the usual inspection, analysis and test of steel, the presence of nitrides and oxides may be overlooked entirely. In the hot working or cold working of the metal into its final shapes, the presence of these gases or their compounds may produce hot shortness or cold shortness, although this effect is frequently attributed to other causes. The fracture test, by revealing a decided brittleness, or the tensile test by indicating a lack of ductility, may issue a warning of the presence of dissolved gases or their solid compounds.

An example of the influence of nitrogen and oxygen upon steel which was recently brought to the attention of one of the authors, announced itself by the brittleness of several specimens of boiler tubing. An investigation of the properties and structure of the tubing was made with the purpose in view of locating the relation between the two.

A microscopic examination[2] of several specimens showed that the metal had, at some stage in the course of manufacture, been over-oxidized,[3] or, more correctly, allowed to absorb and retain an excess of nitrogen and oxygen. Since a sprinkling of nitrides and oxides was visible in the structure the corresponding gases must have been present in the metal in a quantity far in excess of that usually present in ordinary steel. The presence of an excess of gas in the metal may be due to one of two causes:

(a) The absorption and retention of gas by the liquid metal in the refining process, or

(b) The absorption of gas by the solid metal in some of the heating operations subsequent to refining.

Of these two sources of gas contamination, the former, in this case, appeared more probable. A polished but unetched surface of one of the

1. A resume of the literature on the effect of nitrogen in steels has been prepared by Comstock and Ruder, *Chemical & Metallurgical Engineering*, Vol. 22, No. 9, 1920, page 399. The same subject is included in an excellent bibliography compiled by Rawdon, Groesbeck and Jordan, Bureau of Standards, Technical Paper No. 179.

2. Acknowledgment is due the Bureau of Standards, Washington, for the use of the equipment of the metallurgy division for this work.

3. Steel, which has been held too long in the oxidation stage or steel poorly deoxidized frequently is spoken of as oxidized or over-oxidized steel. In the case of over blown bessemer steel, for instance, the possible presence of large amounts of nitrogen would make the designation incorrect.

A paper presented by title at the Indianapolis Convention. A. E. White is director department of engineering research, University of Michigan, Ann Arbor, Mich., and J. S. Vanick is metallurgist Fixed Nitrogen Research Laboratories, Washington.

specimens revealed a precipitation of small globules, sprinkled about in a matrix apparently free from other markings. Under high magnifications, the globules strongly resembled oxides and subsequent etching proved them to be oxides.

A surface representing a cross section showed them to be rather uniformly distributed throughout the matrix, although a slight tendency to form in concentric layers was noticeable. A longitudinal section, however, revealed them in the form of segmented strings or chains. The parallel-string distribution in the longitudinal section is significant in establishing the origin of the oxides. Apparently, oxygen or the oxide of iron has been dissolved in the molten metal and liberated upon cooling. The subsequent rolling and working had moved the particles into parallel rows. The uniform distribution of the oxides in the cross-sections was further characteristic of the precipitation of insoluble compounds from a cooled metallic solution. It is evident that such oxidation that may have occurred in the heating operations subsequent to casting would show a graduation in the quantity of oxide from the surface toward the interior of the sections.

Etching definitely established the position of the oxides with respect to the grain structure and revealed the presence of nitrides. The structures are recorded in Figs. 1 and 2 the difference between the two micrographs having been produced by a change in focus. The deeper color which the nitrides assume and their apparent projection above the reflecting surface, renders them visible above the plane of the image, whereas the oxide inclusions have been found to be more intensely revealed by focusing them below the plane of the image.

Fig. 1, illustrating the position of the oxides, shows them to be irregularly distributed and quite independent of the grain structure. The effect of mechanical working upon these inclusions in marshalling them into segmented cords or chains that agree in direction with the long dimension of elongated slag particles is evident from the micrograph.

The nitrogen compounds which occur in the structure require a closer observation for their detection. A close inspection of the surface discloses the thin, needle-like crystals which, except for their straightness, strongly resemble the short graphite flakes of cast iron. The plates appear to be rather uniformly distributed throughout the body of the tube thus lending support to the supposition that nitrogen has been dissolved in the molten metal, rather than absorbed, in some of the heating operations subsequent to casting.

The type of plate occurring in the specimens examined is shorter than that usually found in fusion welds or ammonia-nitrogenized iron and the number of plates that appear is much smaller. Nitrogen may be retained in solution in iron. It appears that in the present case the feebler precipitation of the nitrides is an indication of the smaller quantity of available compound-forming gas in the metal. A corresponding effect, however, may be induced by the temperature conditions prevailing during the final heating and cooling. For example, Ruder[4] and others, have shown that an absorption and diffusion of the nitride plates, similar to the absorption and diffusion of carbon in steel, takes place upon heating to 650 degrees Cent. Quenching from 650 degrees Cent. and above, prevents the precipitation of the nitride plates. Slow cooling usually permits their formation. However, the conditions necessary for controlling the precipitation of nitrogen compounds and the

4. Ruder, The Effect of Nitrogen in Steel, *Chemical & Metallurgical Engineering*, Vol. 22, No. 9, page 399.

physical effects attending the several types of structure have not yet been thoroughly established.

An interesting feature of the structure which is partly illustrated in Fig. 2 and 7, is the failure of the nitride plates to adopt a directional trend corresponding to the direction of working. For example, the prevailing slope of the plates shown in the center of Fig. 2, is north-west. This slope is inclined at an angle of approximately 45 degrees to the direction of working as marked by the oxide links. Since the tubes were hot worked, the nitrides were evidently in solution and their position in the equi-axed crystals that form upon cooling would be expected to be devoid of directional characteristics. It is possible that the intercleavage slip in the hot-worked crystals followed an angle of approximately 45 degrees to the direction of working. The opinion might then be ventured that the plates tend to form along directions corresponding to the cleavage angle, or in other words, that the plates exert an effort to collect along those cleavage planes that have been subjected to slip. This suggestion implies the ability of the individual crystals to expel their burden of dissolved nitride, much after the fashion of the expulsion of cementite in high carbon steels or the intercleavage expulsion of ferrite in nickel steels. The persistence of lines of flow in the hot-worked crystals in spite of an almost instantaneous recrystallization from the working temperature, through the precipitation temperature must be assumed.

The directional characteristics described above are not consistently maintained throughout the specimens, hence additional evidence of this effect is necessary before the explanation may be accepted. It has been shown that the curved plates formed in the metallic globule inclusions of fusion welds, retain their curved form even after heating to 1000 degrees Cent.[5] This temperature is far above the solution temperature of the nitride plates in the ferrite matrix hence it appears that the cast from which the nitride is absorbed in heating retains its unity until the nitride is again precipitated upon cooling.

Figs. 3 and 4 illustrate the appearance of the nitride patches which are frequently mistaken for the eutectoid pearlite of ordinary carbon steels. To those familiar with the structure of nitrogenized iron, the identification of this constituent offers little difficulty. A weak etching reagent preferably is used and the structure gradually developed by repeated etchings. Nitric or picric acids are suitable for the purpose and boiling sodium picrate or the heat tinting methods adopted by Strauss,[6] may be used to advantage. The important points of resemblance between pearlite and the nitride patch are:

(a) The irregularity in surface contour.

(b) The darkening upon etching.

(c) The common preferences, then present in small quantities to collect at the grain boundaries.

Nitride patches usually lack the laminations characteristic of the iron-carbon eutectoid, pearlite. Instead their surface is roughened by irregular eddies or swirls. Comstock[7] has reported patches composed of fine needles. Frequently, nitride patches are marked by dark, smooth surfaces outlined by straight sides boundaries, which give the patch a definite

5. Rawdon, Groesbeck and Jordan—Technical Paper No. 179, Electric Arc Welding of Steel, Bureau of Standards, Washington.
6. B. Strauss, *Stahl und Eisen*, 1914, Vol. 34, part II, page 1814.
7. Comstock and Ruder, Effect of Nitrogen on Steel, *Chemical & Metallurgical Engineering*, Vol. 22, No. 9, 1920, page 401.

geometrical form quite in contrast to the rounded outline of ordinary pearlite.

In the specimens of boiler tube which were examined, the patches usually consisted of twisted chords which had been entangled into a confused mass. The shapes strongly resembled the irregular forms adopted when a film of water on a glass plate shrinks into pools as surface tension acts to reduce the surface area of the film. Indeed a similar effect occurs in the nitrogen bearing steels; the presence of the gas or its compounds prevents the formation of cementite lamellae and promotes the formation

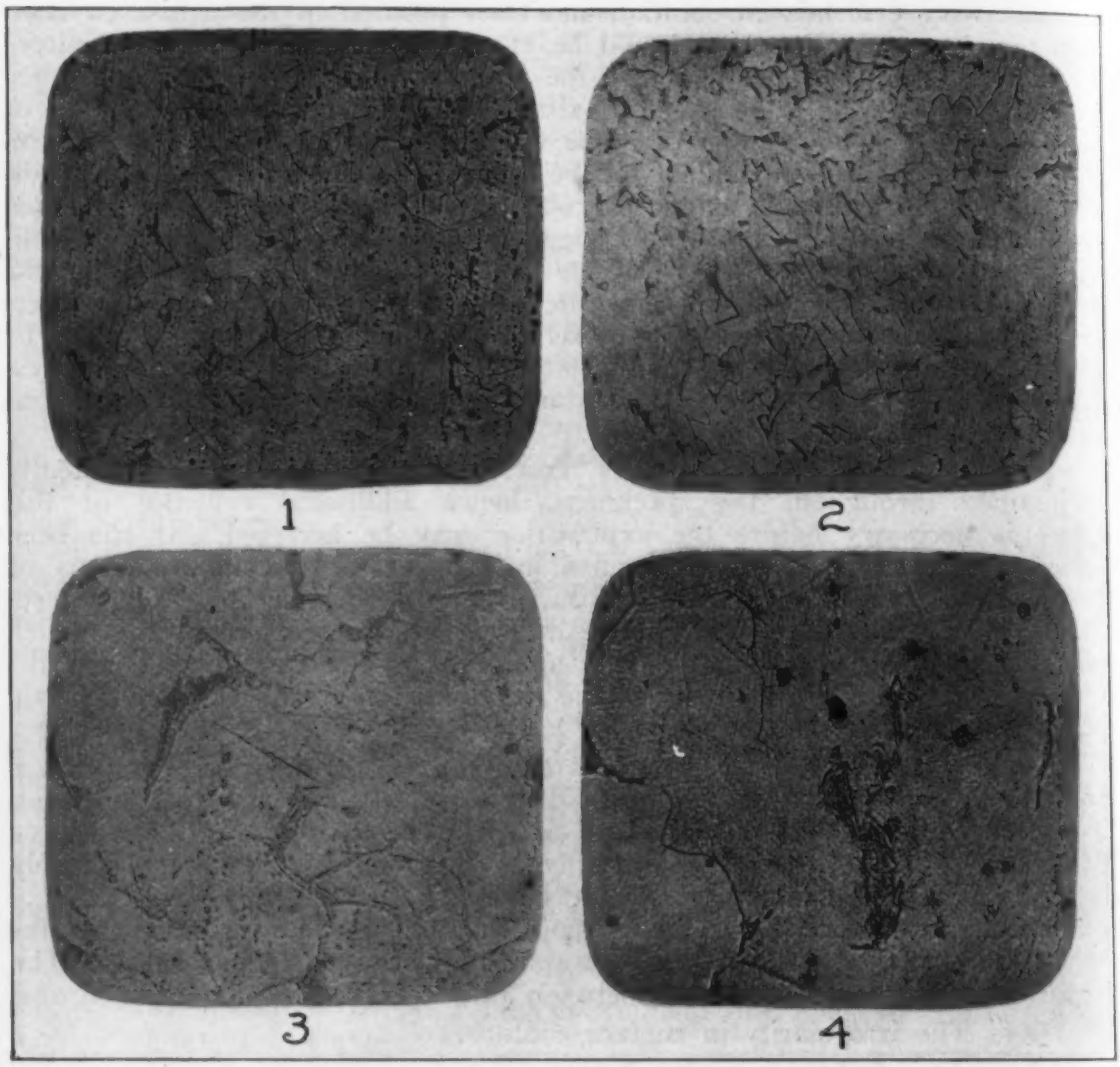


Fig. 1—Micrograph showing oxides in boiler tube steel. X 100. Fig. 2—Micrograph showing nitrides in the steel. X 100. In Figs. 1 and 2, the position of the oxides and nitrides with respect to the structure is intensified by a change in focus. The true image is distorted slightly. Fig. 3—A nitride patch X 500. Fig. 4—Another nitride patch X 500. Specimens shown in Figs. 1-4 were etched with a 2 per cent solution of nitric acid in alcohol.

of the tangled, coagulated chords. Thus the normal positions of the pearlite areas within the matrix is not appreciably altered but their internal structure is completely changed. The change within the nitride patches has been compared to the divorce of cementite in ordinary carbon steels. The conditions which encourage the change within the two types of steel are widely different. For example, the nitrogenized steels[8] are able to develop the di-

8. Note: A specific amount of carbon and nitrogen probably is necessary.

vorced type of structure with high heating and comparatively rapid cooling, whereas the usual cementite divorce requires a long sojourn at lower temperatures and a much slower rate of cooling. In addition, the ductility of carbon steels is usually improved by the cementite divorce.[9] Nitrogen-bearing steels which contain the divorced compound are inherently brittle.

The rapid coagulation of the compound within the nitride patches is indicative of the mobility of this constituent. This effect is partly demonstrated by the rounding of the edges of the nitride patches. The rounding of the edges and the graduation in color intensity from the edge to the interior of the nitride patch imposes the apparent relief effect and produces the brilliant edges that assist in distinguishing the nitrogen contaminated pearlitic patch from the carbon eutectoid pearlite.

The forms of nitride patch which occur in steel obviously may vary through any of the types described above. In specimens such as the boiler tube steel, several types occur within the same specimen. The composition, heat treatment and possibly, gas pressure exert an important influence upon the final structure.

An example of the peculiar forms of nitride compounds that may occur in a nitrogen-bearing steel is illustrated in Fig. 5. A precipitation of fine prismatic crystals has been deposited in a criss-cross manner, thus giving the deposit a trellis-shaped structure. The prismatic crystals possess more body than some of the individual nitride plates which may be traced in the micrograph, thus suggesting that the crystals represent the divorced or coalesced type of nitride. The crystals probably consist of an iron-carbon-nitrogen compound which is replacing what would normally have been a pearlitic area of the low carbon steel. The well developed form of the individual crystals would indicate that the compound possessed a prismatic crystal habit that is able to find expression because of the mobility of the compound. The prismatic crystal habit is also characteristic of cementite hence this observation does not assist in distinguishing the nitrogen compound from cementite. However, in low carbon steels which have been subjected to a divorce anneal, the coalesced cementite invariably is found to adopt a globular form.

In an effort to determine the part played by the oxides and nitrides upon the course of rupture, a fractured edge which contained tributary cracks, was polished and examined. Figs. 6, 7 and 8 illustrate the path of rupture adopted by several of these tributary cracks near the fracture surface. In Figs. 6 and 7, the fissures maintain their direction quite independently of the course of the oxide layers which traverse the surface at an angle of approximately 60 degrees to the fissures. Fig. 8 illustrates the appearance of the terminus of a larger crack in the metal. The prevailing direction of the crack has not been altered but its continuity has been repeatedly interrupted. The continuity of the rupture has been broken at the grain boundaries.

This course of rupture is quite in agreement with the characteristic paths of rupture followed in a steel that is free of such inclusions or compounds as the oxides or nitrides. Within certain grains a sharp change in the direction of the path of rupture has been enforced. The failure of the path to cleave the crystals in a straight line may be attributed to the specific internal structure of the individual crystals. The sharp changes in the course apparently are due to the obstructions raised by crystals, which by

9. Howe, The Metallography of Steel and Cast Iron, page 394.

virtue of an orientation that is unfavorable to the line of rupture, possess a greater resistance in that direction. For example, Fig. 8, shows the course of the crack sharply changed in crystal *a*. The directional change evidently is caused by the unfavorable orientation of the cleavage planes in the crystal, with respect to the prevailing path of rupture.

In describing the type of fracture that is frequently found in fusion welds, Miller has attributed its intercrystalline course to the presence of oxides at the grain boundaries. It would be reasonable to expect from the results of Miller's observations, that the impurity content of the weld was sufficiently great to invite intercrystalline rupture. The oxide and nitride inclusions in the boiler tube specimens, do not appear to be present in sufficient quantity nor located in sufficiently strategic positions to divert the path of rupture. The preference of the path of rupture for the crystal centers suggested that the inherent brittleness of the crystals themselves invited this course. The cleavage brittleness of the crystals is reflected in the comparatively straight fractures within each individual. Were the crystals possessed of the ductility of ordinary ferrite, the stresses set up in the rupture of the metal would strive to adjust themselves by the flow of the ductile crystals. However, no evidence of distortion or deformation is visible near the fracture. The brittleness of the individual crystals, appears to be responsible for the ultimate brittleness of the metal. The cleavage brittleness of the individual crystals suggests the presence of gases in solution.

Nitrogen and oxygen and their compounds may be introduced into steel in the melting or in subsequent heating operations. Manufacturing conditions may be concentrated into two physico-chemical problems which consist of a study of the temperature-concentration relations between the gas on one hand and the liquid and solid metal on the other.

In both cases, the metal can absorb or dissolve a definite amount of gas and upon cooling, retain a certain portion of the gas within itself either in solution or in the form of compounds. Practical examples of the gas-liquid metal problem are found in the refining of steel or in the manufacture of fusion welds. Examples of the gas-solid metal problem are evident in the nitrogenization of steel by ammonia, or furnace gases, and the oxidation of steel, or scaling. Unfortunately the problems are further complicated owing to the gases being most active when present in compound form such as air, ammonia or steam. Comparatively high temperatures usually are necessary before the reactions become rapid although the decomposition of air and the oxidation of steel become perceptible at 150 degrees Cent. at which temperature a polished surface is tinged with the pale yellow temper color. It is evident that iron or steel are capable of cracking air into its two principal components, oxygen and nitrogen. The scaling of steel surfaces upon heating is a common form of oxidation. A similar action occurs when ammonia is cracked by iron or steel into its components, nitrogen and hydrogen.

The large volume of nitrogen, or its compounds contained in waste gases resulting from the combustion of oil, gas or coal is known to penetrate the surface of metal exposed to it. A typical case of such contamination has recently been described by Blue[10]. Apparently high temperatures are necessary for this penetration. Below 650 degrees Cent. the influence of oxygen and nitrogen is limited to surface contamination. Above 650 degrees

10. *Iron Age*, Vol. 108, No. 1, page 1, July, 1921.

Cent. a solution and diffusion of nitrogen occurs and a similar behavior might be expected of oxygen.

Above the melting point of iron the quantity of gas soluble in the liquid metal reaches large proportions. When it is borne in mind that a

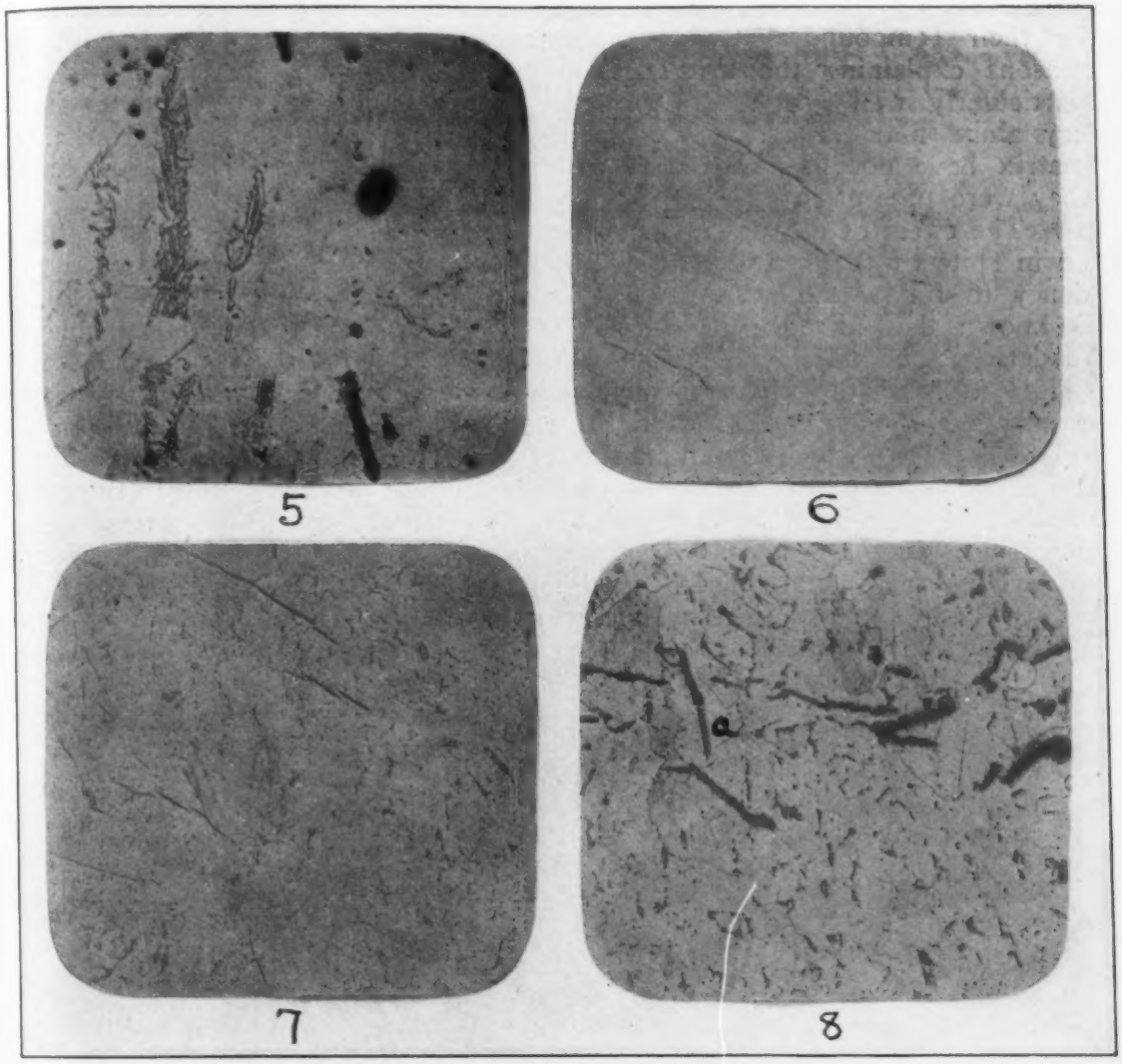


Fig. 5—A nitride patch in boiler tube steel, showing prysmatic type of nitrides. X 1000. Figs. 6-8—Specimens illustrating prevailing transcrystalime course of rupture through the metal. X 100. Fig. 6—Unetched surface showing minute fissures in fracture zone. Fig. 7—Surface shown in Fig. 6 after etching with a 2 per cent solution of nitric acid in alcohol. Fig. 8—Terminal of a tributary fissure from the fracture surface. Etched with a 2 per cent solution of nitric acid in alcohol.

unit volume of steel containing 0.1 per cent of nitrogen has dissolved roughly 6 volumes of the gas, the values become more impressive. The facts stated above, are mentioned for the purpose of calling attention to the need of further work upon the physico-chemical relations between metals and gases.

Since the equilibrium relations between oxygen, nitrogen and steel and the resulting mechanical properties have not been studied widely, the quantity limits within which the gases and their compounds are destructive to the properties of the metal, remain in doubt. Small quantities of dissolved nitrogen are known to produce brittleness in low carbon steel and carbon-free iron. Oxygen might be expected to affect the metals similarly.

The quantity of oxygen and nitrogen in the form of oxides and nitrides which may be present in iron and remain microscopically undetected, has not been thoroughly established. When available in the metallic solution in sufficient quantity to form microscopically visible compounds, a noticeable brittleness of the metal has been attributed to the presence of the gases or their compounds. Oxides repeatedly have been associated with the reasons explaining the brittleness of steels. The explanations have been particularly well grounded when the oxides could be identified as intercrystalline films or inclusions. Oxides which are distributed through the matrix have not been regarded with the same degree of suspicion unless they were present in excessive quantities.

The effect of nitrides upon the brittleness of steels is similarly interpreted in spite of the fact that the course of rupture has not expressed a tendency to follow the positions of the nitrogen compounds in the metal. It is known that nitrogen in solution, and therefore invisible, is capable of rendering the individual crystals brittle. The presence of nitrides and oxides in comparatively large colonies suggests that the metal contains the corresponding gases in solution, in a quantity that exceeds the limits of solution within which the influence of the gases is not detrimental. From the examination of the specimens of boiler tubing described, the nitrides and oxides micrographically illustrated in this paper; and the corresponding gases in solution, particularly nitrogen, are present in sufficient quantity to account for the brittleness of the metal. The particular course of the path of rupture suggests that nitrogen in solution, is the dominating cause of the brittleness.

CARBONIZATION WITH WOOD CHARCOAL

By H. Schagrin

IT WOULD be safe to say that ordinary wood charcoal alone, when considered in comparison with wood charcoal plus so-called energizers, is little used at the present time. Charcoal has been used and discarded by many hardening and carbonizing rooms but not always for the same reason. The experiments given in this article has been performed on a regular commercial scale to determine the carbonizing effect produced by the use of wood charcoal alone.

In the industry the action of absorption of carbon by steel when heated to the proper temperature for an hour or two in intimate contact with a carbonaceous material is known as case carbonizing, while the same process when extended over a considerable length of time, say a week or more, and where the pieces treated are large with consequent absorption of much carbon, is known as cementation. The former treatment, or case carbonizing using wood charcoal only, is the one under discussion in this article.

In general, to overcome the drawbacks encountered through possible brittleness, the practice of case hardening, or producing a high carbon case on a soft piece of steel is resorted to. There is room for argument and there is considerable diversity of opinion as to whether case hardening is the only recourse at all times, or whether the entire piece of higher carbon and sometimes plus alloys properly heat treated, would not serve the purpose equally well.

With proper treatment of a case carbonized piece after removal from the furnace, and with the elimination of the rather sharp line of demarcation between the high carbon case and low carbon interior, the result obtained is a piece of steel having the desired hard surface with a backing of soft, tough and malleable steel. In short, the latter will not stand wear or abrasion, since it is easily deformed, whereas the former is able to withstand the necessary wear and abrasion. The material used in these tests were drop forgings made from acid bessemer steel of composition approximately: Carbon, 0.15; manganese, 0.70; sulphur, 0.050; phosphorus, 0.060 per cent. The pieces were cheap and it is to be noted that the care and time expended in packing did not compare with that for pieces such as gears, which necessarily must be almost perfect.

For reasons given later, and explanation of the carbonizing action as understood, it was not deemed essential to take any special precautions as to mesh of the charcoal, although the material was a powdered mixture with pieces up to 30 mesh. Such precaution as observing that the carbonizing material was free from moisture was considered a routine one, but always should be strictly observed. The procedure followed was to place a layer of charcoal to a depth of one inch on the bottom of the carbonizing box, pack in one layer of forgings each about 12 inches long as closely as possible, cover with charcoal and see that there was no pockets by using a wooden ram; adding another layer of forgings and repeating until about even with the top. Charcoal was then heaped on top of the forgings, the cover pressed down, and the opening around the cover raised at times an inch from the box, and finally luted with a mixture of ordinary clay and water.

A paper presented at the Indianapolis Convention. The author, H. Schagrin is chief chemist, United States Naval Ordnance Plant, Charleston, W. Va.

After the boxes were removed from the furnace, it was often noticed that as much as one fourth of the charcoal had been burned, indicating considerable leakage of air into the box because of the cracking of the clay luting. Such condition can be remedied easily by the use of more modern appliances, for example, carbonizing boxes with grooved covers.

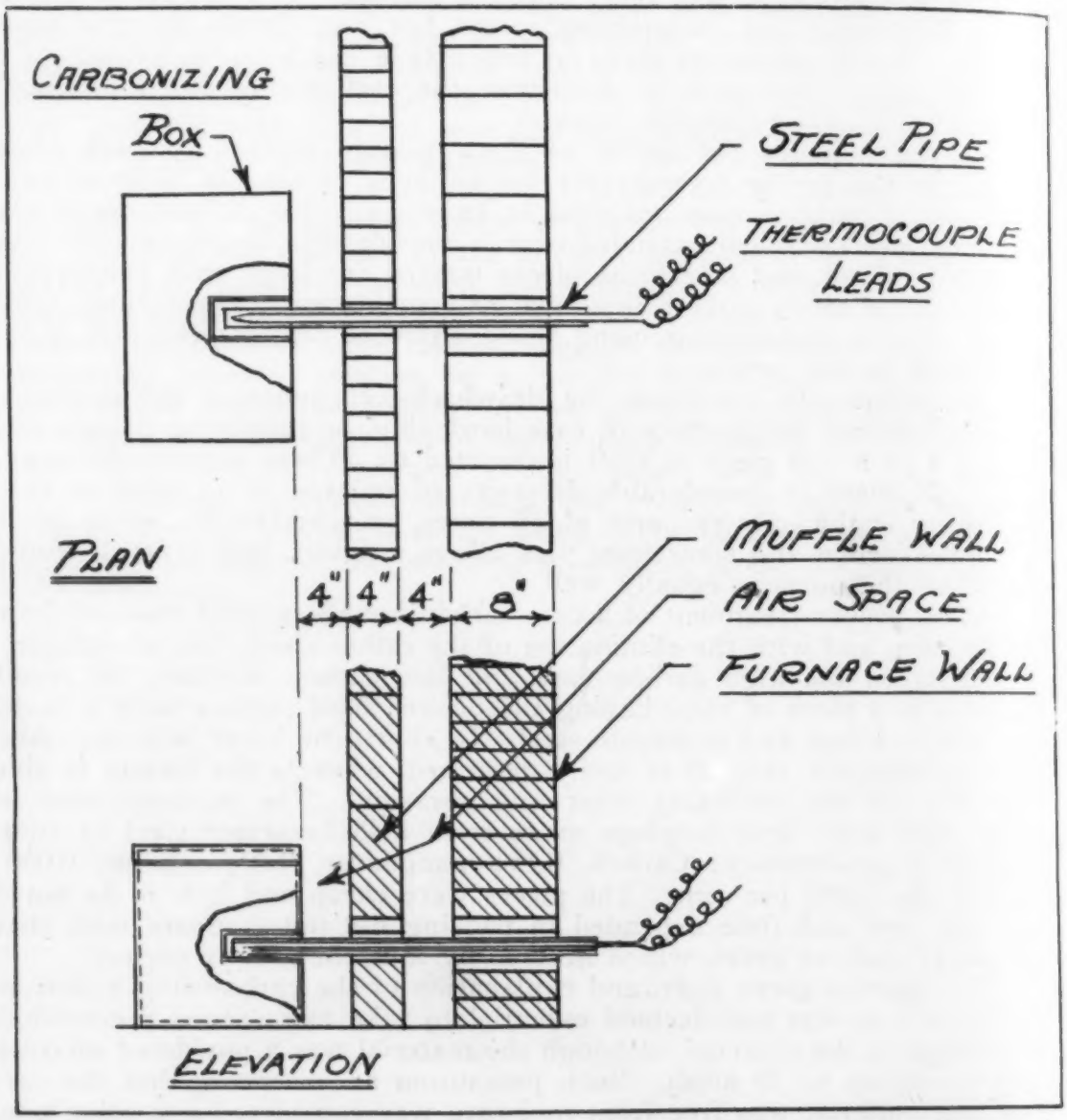


Fig. 1—Thermocouple arrangement used in the wood charcoal carbonizing process. Three couples were used in each furnace, each inserted in the carbonizing box as indicated.

In spite of production operations just outlined, the forging when allowed to cool in the boxes, then covers removed and the pieces taken out, showed a silvery color indicative of very little surface oxidation. The statement made above that a good portion of the charcoal had been consumed by air leakage, does not necessarily mean that the air came directly in contact with the pieces to be carbonized. The air, from the evidence at hand, must have combined with the charcoal to form the oxide gas carbon monoxide which we know is the real factor in carbonizing.

All up-to-date hardening rooms are now equipped with pyrometers.

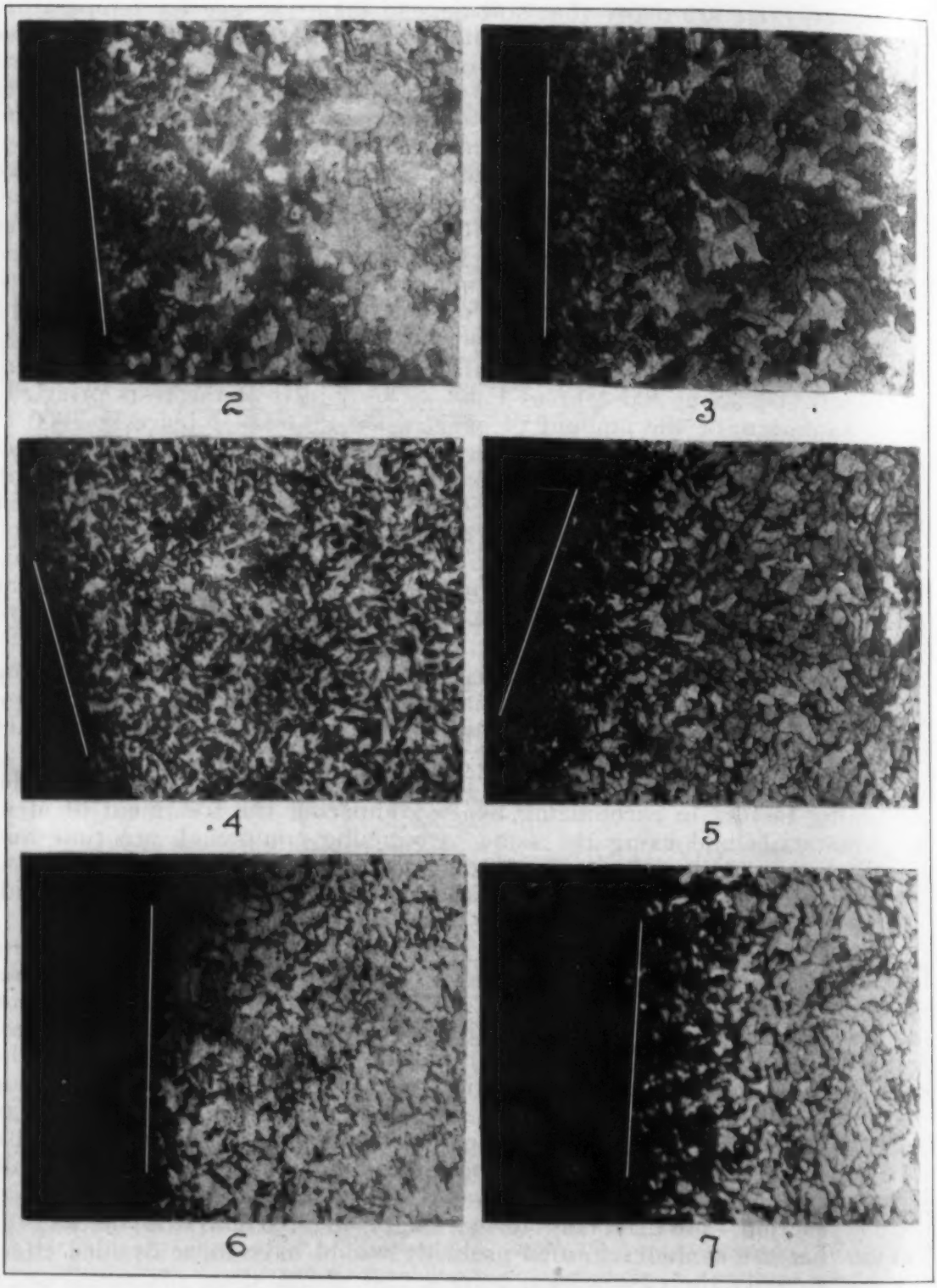
However, there are many that still depend upon the eye for temperature reading. In such cases, where failure of parts results, it is of course impossible to consistently trace trouble. There has been a great deal written on the proper placing of thermocouples in doing carbonizing work, and care as well as common sense must be exercised in maintaining a uniform temperature in a furnace where there are a number of burners. If the fuel be oil fed from a pump, care must be taken to see that the pulsating action of the pump does not have a direct effect upon the flame. During these experiments some trouble was caused by water in the fuel oil. If the fuel be gas, the proper precaution must be taken to see that the flow of gas is maintained at a constant pressure. The condition of the burners must also be such that the temperature can be regulated easily. The location of the burners are of equal importance.

The carbonizing boxes were all charged when the furnace was at a temperature about 300 degrees Fahr. The objects of the tests primarily were to determine the amount of penetration that takes place at 1400 to 1500 degrees Fahr. and at excessively high temperature, say 2000 degrees Fahr. Heat treatments are not discussed. Close control was kept at all times on the temperature of the pieces to be carbonized by having the fire end of the thermocouple set in the middle of the box. As an optical indication to the treater, a bar 4 x 4½ inches of the same steel as that being carbonized was inserted in the box in such a way that it could be withdrawn to note the color. This, however, was for the instruction of the furnacemen.

Other work with various kinds of carbonizing materials containing charred leather, powdered bone, charcoal and prussiates in varying proportions, has proven that absorption of carbon by the steel first takes place at about 1400 degrees Fahr., but to produce even a light case at this temperature would require a prohibitive length of time. The determining factors in carbonizing, when comparing the treatment of identical materials and using the same carbonizing compound, are time and temperature. Although it is evident that some carbonizing begins at 1400 degrees Fahr., the time of carbonizing properly should be considered from the time the work has reached the temperature desired.

The standard mixture of 60 parts charcoal and 40 parts barium carbonate intimately mixed gives good results, but is costly. The reaction claimed during carbonizing for this mixture, as forming carbon monoxide and cyanide of barium with the nitrogen of the air, seems less probable than the reaction by which carbon dioxide is released from the carbonate, the carbon dioxide reacting with the charcoal to give carbon monoxide. The next cycle will release oxygen as soon as absorption of carbon takes place, to form more carbon monoxide. The idea has also been advanced that the ash of wood containing alkali carbonates, would form alkali cyanides with the nitrogen of the air. This is doubted, as is the reaction above for the formation of the barium cyanide for the reason that the cyanides formed probably would have more decided effect than is actually the case.

To withstand bending stresses, it is not desirable to carbonize to more than 1.00 per cent carbon. Satisfactory results were obtained by maintaining the work at temperature of 1850 to 1900 degrees Fahr. for one hour. For production work, this allowed two charges per furnace for a working day of 10 hours. It was found that charcoal was a cheap and satisfactory casing material where a normal penetration of about



White lines appearing on these micrographs indicate edges of pieces. Fig. 2—Specimen carbonized at 1450 degrees Fahr. for 1½ hours. Quenched in water from box. X 100. Fig. 3—Specimen carbonized at 1450 degrees Fahr. for 1½ hours and cooled in furnace. X 100. Fig. 4—Specimen carbonized at 1500 degrees Fahr. for 1 hour and quenched in water from box. X 100. Fig. 5—Specimen carbonized at 1500 degrees Fahr. for 1 hour and cooled in furnace. X 100. Fig. 6—Specimen carbonized at 1550 degrees Fahr. for 1 hour and quenched in water from box. X 100. Fig. 7—Specimen at 1750 degrees Fahr. for 1 hour and cooled in furnace. X 100.

1/16 inch for about 1½ to 2 hours carbonizing period was desired. For periods over a greater length of time than indicated, other compounds must be present with the charcoal to cause a deeper penetration.

Discussion of Mr. Schagrin's Paper

MR. HILLMAN: I would like to ask Mr. Shagrin what kind of wood he would use?

MR. SCHAGRIN: This is a regular factory operation, and pieces all the way from forgings that weigh up to about ten pounds down to pins were carbonized. Therefore, I wouldn't want to say exactly what kind of charcoal it was. We had to use most everything at the time.

MR. HILLMAN: I have had some experience with carbonizing with wood, and the results were absolutely nil. Carbon heated in a furnace doesn't form dioxide very readily. I was always under the impression, and I believe that various authors substantiate my opinion, that in order to get the active vehicle, that is, carbon monoxide, you must have an energizer such as a carbonate. Carbon dioxide, which acts upon the carbon, forms carbon monoxide, which acts as the carbonizing agent. If you got carbonization with wood charcoal alone I think it is very probable that the particular type of wood that you used contained potassium salts, such as potassium carbonate, and they acted upon the carbon to form the carbon monoxide, which gave you the carbonizing action. Your paper is very interesting, indeed, and if you could prove by photomicrographs by measuring the depth of carbonization, that you have effected carbonizing action by means of wood charcoal alone, and that it can be repeated, I think it is a marked advance in science.

MR. SCHAGRIN: I would like to say this is a factory operation carried on on a tonnage basis and has been for years, at a certain plant, and for that reason, since it was a departure from every day practice, I thought the fact would be interesting. We use various kinds of wood, although some do have more alkali salts in the ash than others, but the facts remain, the results are produced. Nothing else is put in but the ordinary wood charcoal, so I am taking the results as the proof of the pudding.

MR. HILLMAN: You don't know one of the types of wood, do you?

MR. SCHAGRIN: Yes, we had some hickory and quite a lot of pine, but we used most everything, for the reason that we had to take what we could get at the time. I discussed in my paper why I believe the reaction that took place was started by whatever little air happened to be in the box, starting the reaction of oxygen plus the carbon in the wood ash to form carbon monoxide. That I believe would start the cycle.

MR. HILLMAN: What is the nature of your case after quenching? Is it martensitic?

MR. SCHAGRIN: The case was martensitic.

MR. HILLMAN: Isn't it a fact that you will obtain an extremely coarse core in carbonizing at such extremely high temperatures?

MR. SCHAGRIN: I have found from the results here that it is necessary to heat higher with wood charcoal to get the proper penetration. I had to go up to 1850 to 1900 degrees Fahr.

MR. HILLMAN: Don't you believe that high heating is bringing you back to the old cementation process?

MR. SCHAGRIN: That is the reason it has always been said

that heating with wood charcoal causes a coarse case, because it is necessary to heat it higher. But one point I wish to bring out again is that these were not special pieces and must be case hardened in a cheap way.

MR. HILLMAN: You quench in the box, then?

MR. SCHAGRIN: Yes, from the box.

MR. HILLMAN: What is the maximum depth of case that you obtained?

MR. SCHAGRIN: I have obtained slightly more than 1/16 inch.

MR. THUM: Could I ask the temperatures you are using in carbonizing in the process that you have just described?

MR. SCHAGRIN: Slightly over 1900 degrees Fahr. The furnace temperatures would run up as high as 1950 degrees Fahr. in the every-day work, because the men have so much to watch.

MR. THUM: I would like to point out that the process of cementation was used for a good many years in the cutlery trades with wood charcoal almost exclusively. They like to use charcoal only on account of the fact that they can depend on it. It is something that is uniform. Just as soon as they put burnt leather or other things in, they run into trouble. Also, it is well for everyone to be on the lookout in the reading of literature, and especially in interpreting results from commercial carburizers at the present time, due to the fact that nitrogen has a great influence on the carburizing process. It is difficult to distinguish the eutectoid produced by nitrogen and the eutectoid produced by carbon. They both have practically the same results in making a hard and brittle case. Consequently when you run into peculiar results in carburizing with leather, for instance, you have a case which is quite hard on quenching and yet if you analyze the outer edge you will find you have only 25 or 30 points of carbon, which is much too small to get the specific hardness which is desired.

CHAIRMAN HARTZELL: I would like to ask the gentleman who just spoke. In the cutlery business you use charcoal—you spoke of leather charcoal—have you tried the wood charcoal?

MR. THUM: Wood charcoal is what I meant to say.

MR. SCHAGRIN: In one particular case of hardening compound that I made an analysis of lately for very deep penetration, I found iron oxide—that is an every-day energizer, and I found carbonate of calcium, which is supposed to break up completely into carbon dioxide and calcium oxide at a lower temperature than carbonizing temperature. Some of those things which we consider impossible are sometimes found to be every-day results. We know that energizers are very good, but this happens to be a plant example of production work, and I thought the idea might be of some use to others.

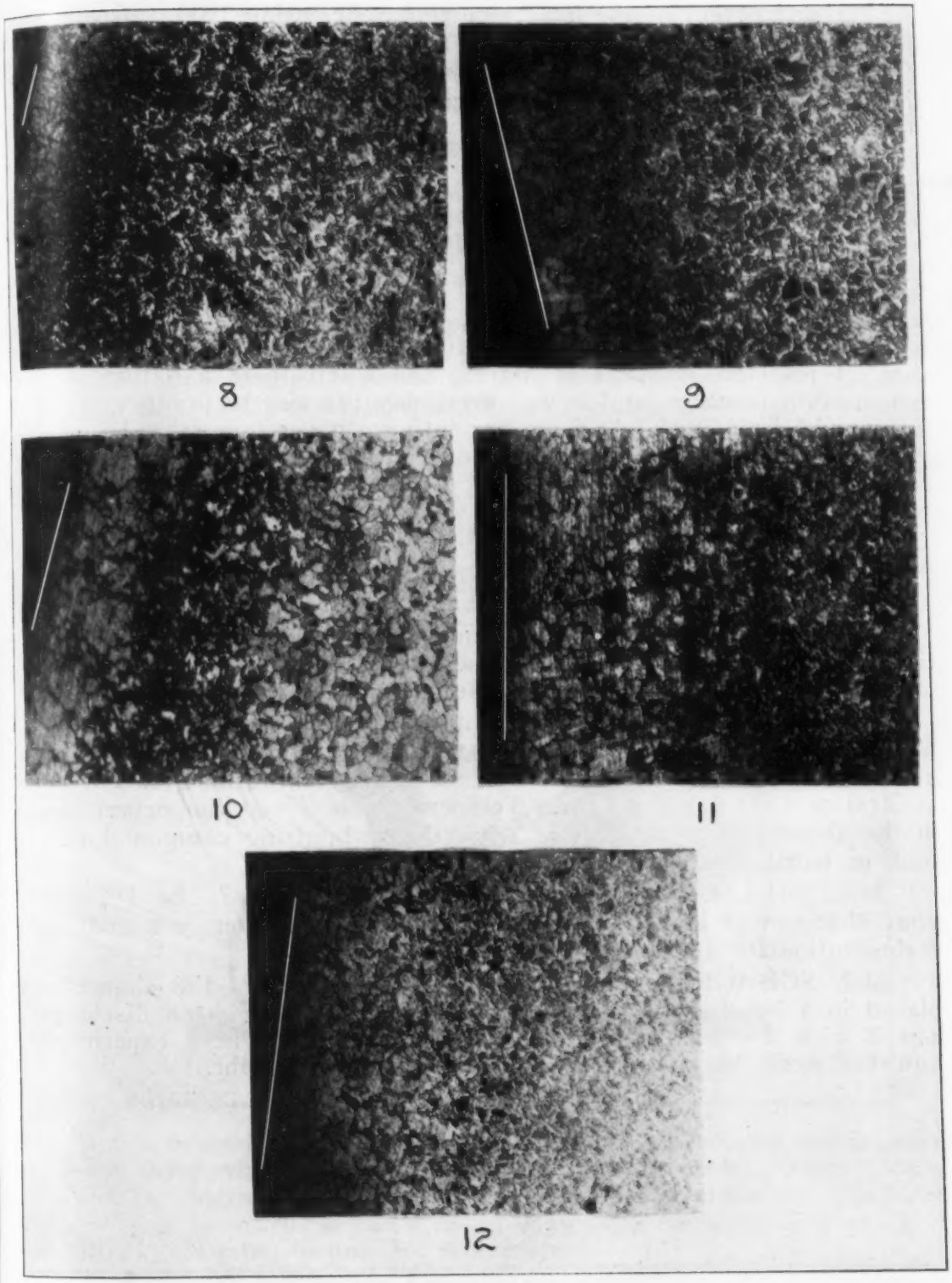
MR. HILLMAN: Can you re-use this compound?

MR. SCHAGRIN: No.

MR. HILLMAN: You cannot use it more than once?

MR. SCHAGRIN: Oh, yes, we take it out; it suffers a great deal of loss, but we do re-use it. The ash is so light that we depend almost on the ventilation of the room, the blowers and fans, to take the ash away, and shovel the rest of the material into the charcoal bin and use it over again.

MEMBER: I would like to ask Mr. Schagrin what he found was



White lines appearing on these micrographs indicate edges of pieces. Fig. 8—Specimen carbonized at 1900 degrees Fahr. for 1 hour, cooled in furnace, reheated, quenched in water from 1400 degrees Fahr. It shows surface decarbonization from reheating but the case is clear. X 100. Fig. 9—Specimen carbonized at 1900 degrees Fahr. for 1 hour, quenched in water from box, reheated, quenched in water from 1400 degrees Fahr. and drawn at 800 degrees Fahr. X 100. Fig. 10—Specimen carbonized at 1900 degrees Fahr. for 1½ hours, cooled in furnace, reheated, quenched in water from 1400 degrees Fahr. and drawn at 800 degrees Fahr. X 100. Fig. 11—Specimen carbonized at 1950 degrees Fahr. for 1 hour, cooled in furnace, reheated, and quenched in water from 1750 degrees Fahr. It shows surface decarbonization from reheating but the case is clear. X 100. Fig. 12—Specimen carbonized at 2000 degrees Fahr. for 1 hour, quenched in water from box, reheated, quenched in water from 1400 degrees Fahr. and drawn at 800 degrees Fahr. X 100.

the carbon content of the hypereutectoid zone, using 1900 degrees Fahr. as the carbonizing temperature?

MR. SCHAGRIN: I think the highest carbon content we were in the habit of getting was slightly over 1.00 per cent, and we try to keep it a little under 1.00 per cent for the reasons stated.

MEMBER: Is the free cementite very pronounced?

MR. SCHAGRIN: When we went up to 2000 degrees Fahr. it was pronounced, but we had to go up to 2000 to get it pronounced.

MR. HILLMAN: Did you ever etch with sodium picrate and prove it was cementite?

MR. SCHAGRIN: Yes.

MR. NELSON: I think I might throw a little light on the question. I just left England in March, and I left there a battery of six cementation furnaces, and it was every-day practice to produce the old-fashioned blister steel. As I am presenting a paper tomorrow I can give you the depth of penetration of various millings from the outside to the center of the blister bar produced by the old-fashioned cementation process with the charcoal.

MR. HILLMAN: I am strictly in accord with the old cementation process, but if I speak correctly, it takes seven days, doesnt it?

MR. NELSON: It takes anywhere from 7 to 21 days.

MR. HILLMAN: This gentleman says that he can get carburization in one and one-half hours. How long does it take you to get your steel to the carburization temperature?

MR. SCHAGRIN: I would like to say that cementation takes place, but it must be remembered that this carburizing is done at a higher temperature than ordinarily. Ordinarily carburizing is not done at 2000 or 1900 degrees Fahr. Temperature is a very important factor in the absorption, regardless of what the carbonizing compound is. It took us usually between 1 and 1¼ hours.

MR. HILLMAN: That is with a cold furnace? In 1¼ hours your charge was heated up to 2000 degrees Fahr. then you continued carburization for 1½ hours?

MR. SCHAGRIN: No, where it took 1¼ hours the charge was placed in a hot furnace. A furnace that had recently been discharged, and it took 1¼ hours to bring the contents up. These experiments, however, were charged into a furnace at 300 degrees Fahr.

AUTOMATIC COMPENSATION FOR VARIATIONS IN TEMPERATURE OF COLD ENDS OF THERMOELECTRIC PYROMETERS

By William H. Bristol

FOR measuring high temperatures, such as are employed in the heat treatment of steel, the thermocouple has proved to be the most practical and extensively used device. Certain definite laws of nature govern the operation of the thermocouple. These laws or fundamental principles are for the most part simple. It is a well known fact that a thermoelectric couple made of two properly selected alloys will produce an electric current, the electromotive force of which depends upon the difference in temperatures between the two ends of the cupola, and consequently any variation of temperature of the cold end will change this electromotive force.

Ordinarily the hot junction of the couple is placed in the furnace

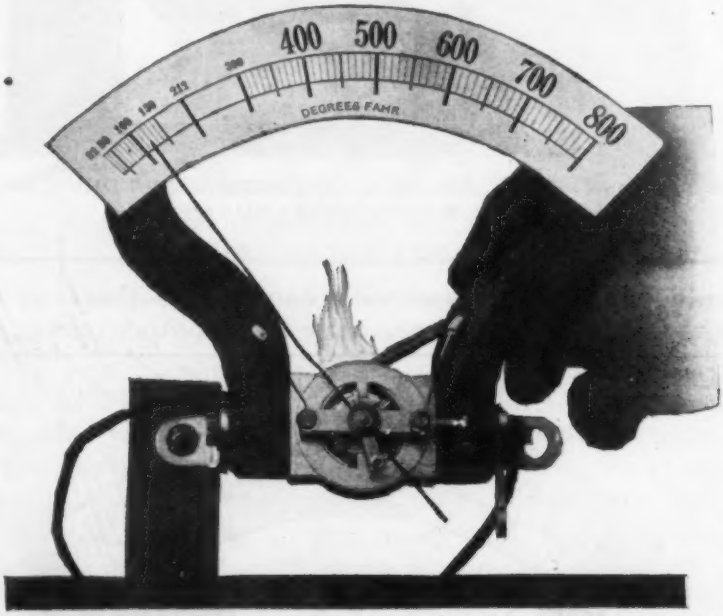


FIG. 1—INTERIOR VIEW OF OPERATING ELEMENT OF A PYROMETER SHOWING THE INDICATING ARM AND SCALE

where it is desired to measure the temperatures and the cold end is placed at some point where it is exposed to atmospheric temperatures. Variations of the electromotive force produced by the thermoelectric couple are indicated or recorded on the scale of a suitable electrical measuring instrument, calibrated in units of temperature.

To have the instrument give correct indications of the temperature at the hot end, it is evident that it will be necessary to either maintain a constant temperature at the cold end, or to provide means to compensate for changes of temperature at the cold end. Various methods have been tried for maintaining the cold end at a constant temperature,

A paper presented at the Indianapolis Convention. The author, William H. Bristol, is president, The Bristol Co., Waterbury, Conn. In absence of the author the paper was presented by H. L. Griggs, general sales manager, The Bristol Co.

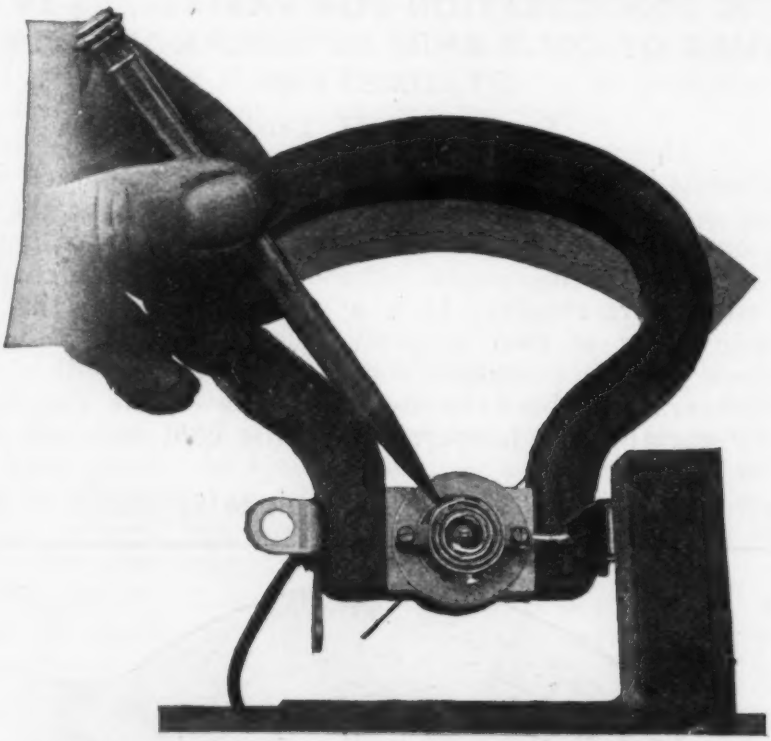


FIG. 2—A CLOSE VIEW OF THE COMPENSATING DEVICE IN THE PYROMETER INSTRUMENT

but under industrial and commercial conditions, there is a great need for making the pyrometer automatically self compensating, regardless of

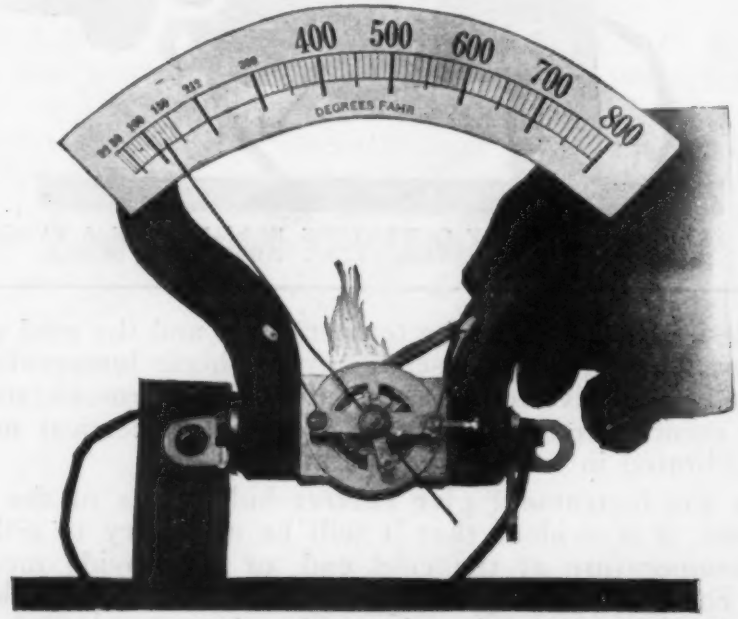


FIG. 3—EFFECT OF A LIGHTED MATCH ON COMPENSATING SPIRAL AND INDICATING ARM

atmospheric changes of temperature which may take place from time to time.

Since the electromotive force upon which the measuring instrument depends for its operation is a function of the difference of temperature between the hot and cold ends of the thermoelectric couple, it will be seen readily that errors will be indicated on the measuring instrument if the cold end temperature varies, and these errors will be equal approximately to the amount of such variations.

By way of illustration suppose the temperature of the hot end in a furnace is 1500 degrees Fahr. and the cold end of the couple exposed to room temperature is at 75 degrees Fahr. If the room temperature should rise from 75 to 125 degrees while there was no change of the temperature of the hot end in the furnace, the difference of temperature between

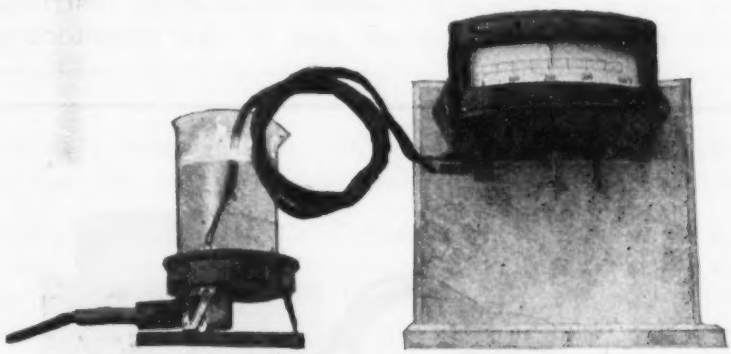


FIG. 4—A COMPLETE COMPENSATING INSTRUMENT ASSEMBLED AND READY FOR USE

the hot and cold end before the rise would have been 1425 degrees Fahr., while after the rise in the room temperature, this difference would be reduced from 1425 to 1375 degrees Fahr. This latter difference would generate less electromotive force and consequently there would be a reading on the instrument below the true reading corresponding to 50 degrees, independent of the type of electrical measuring instrument.

Should the temperature of the room fall, the difference of temperature between the hot and cold ends would be increased and a greater electromotive force would be generated, producing a reading which would be too high. Such errors as these are often caused by the neglect or oversight of this fundamental principle of the thermoelectric couple.

By the aid of several illustrations it will be shown that when the automatic cold end compensator is used in a pyrometer made by The Bristol Co., Waterbury, Conn., the temperature of the cold end may vary over a range of 100 degrees Fahr., but the reading on the instrument still will be correct. To give a clear idea of the compensating device, the author will show how it is made and mechanically applied to the moving element of the electrical measuring instrument.

Fig. 1 is an interior view of the operating element of a pyrometer, showing the indicating arm and scale. When the instrument is turned around, the automatic compensating device can be seen to consist of a bimetallic coil or spiral as shown in Fig. 2. The inner end of this spiral is fastened rigidly to the frame and the outer end connects to the free end of the control spring. It will be evident that any change of temper-

ature to which this measuring element is exposed will cause the compensating spiral to wind up or unwind in proportion to the temperature changes, and thereby mechanically to move the indicating arm up or down the scale in the same proportion, quite independent of any thermocouple or current flowing through the instrument.

Operation of the compensating spiral when subjected to temperature changes, as for instance when heat is applied with a lighted match held near it is that the indicating arm moves upward on the scale, as shown in Fig. 3. When the match is removed, the pointer will return to its original position on the indicating scale. From this it will be seen that the indicating pointer takes a position on the scale corresponding to the temperature of the bimetallic compensating spiral.

If we now use a complete pyrometer measuring instrument provided with bimetallic compensating spiral, and if the thermocouple used for

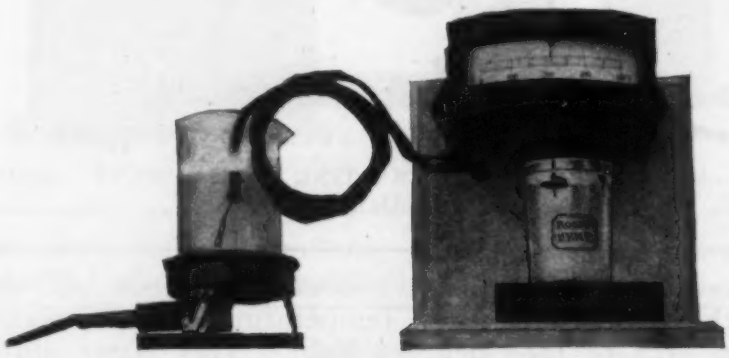


FIG. 5—HOT END IMMERSED IN BOILING WATER AND COLD END AND COMPENSATOR BOTH IMMERSED IN WATER AT ROOM TEMPERATURE

measuring temperature is extended so as to reach inside of the instrument, it is evident that any change of room temperature that occurs will raise or lower the temperature of the whole instrument, including the enclosed cold end of the thermocouple, and the bimetallic compensating spiral. The resultant effect on the complete instrument when in operation is that the cold end temperature errors will be corrected for.

To make it convenient to apply different temperatures quickly to both compensator and the cold end, which are usually located within the instrument, and to make it possible to show the effects of these various changes, a complete instrument is shown in Fig. 4. Two holes have been drilled in the bottom of the case of this instrument, and both compensating spiral and the cold end of the thermocouple have been brought out through these holes on the lower side of the case, and located so that temperature of either one can be raised or lowered independently of the

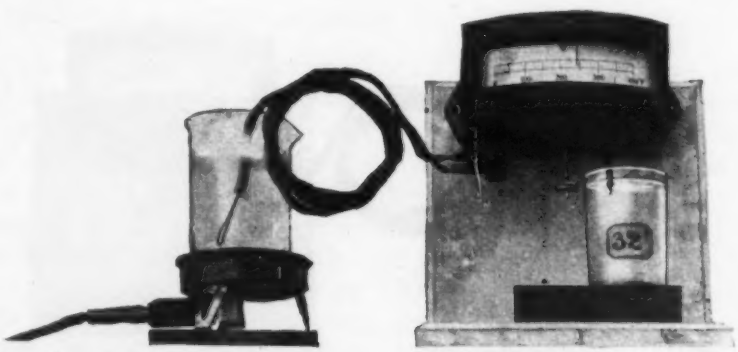


FIG. 6—HOT END IMMERSED IN BOILING WATER AND COLD END IMMERSED IN ICE WATER

other, and so that both can be subjected to the same temperature conveniently by the use of vessels of water at different temperatures.

The hot end of the flexible thermoelectric couple is immersed in a glass of boiling water and is maintained at a temperature of 212 degrees Fahr. on an electrical heater, as is shown by the indicating pointer in Fig. 4 . When the hot end of the couple is removed from the water, the indicating pointer immediately indicates the fall in the temperature and upon returning the hot end to the water, the reading on the instrument immediately will be brought back to its original point on the scale, 212 degrees Fahr., that of the boiling water.

During the experiments with the compensating device and the cold end of the thermocouple, the hot end will remain in the boiling water, which will be maintained constantly at 212 degrees Fahr. so that all variations and experiments upon the cold end and compensator will be quite independent of any changes at the hot end of the thermocouple, thus

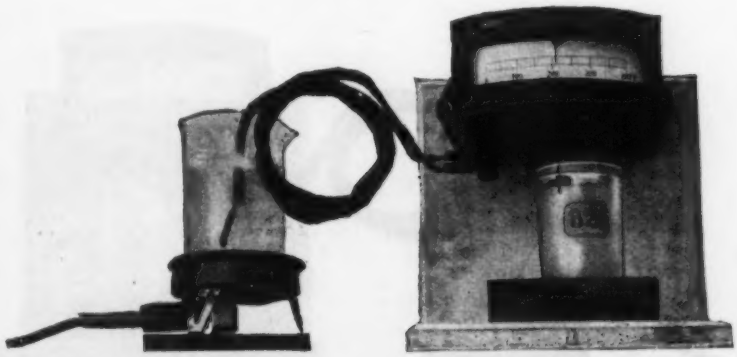


FIG. 7—HOT END IMMERSED IN BOILING WATER AND COLD END AND COMPENSATOR IMMERSED IN ICE WATER

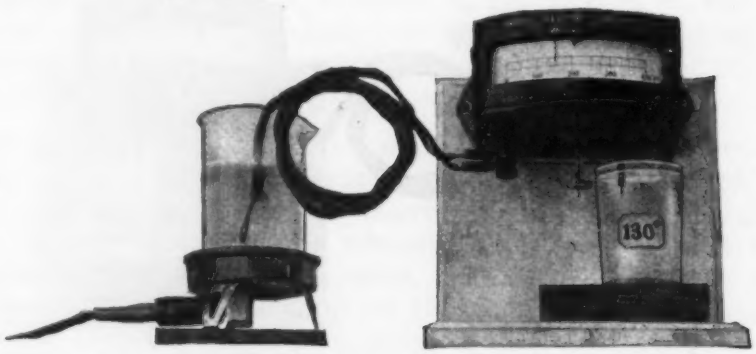


FIG. 8—HOT END IMMERSED IN BOILING WATER AND COLD END IMMERSED IN WATER AT 130 DEGREES FAHR.

making it a simple matter to observe readily the operation of the compensating device and effect of temperature changes that are applied to the cold end of the couple.

To demonstrate that the temperature of the cold end of the thermocouple and the compensator are at exactly the same temperature as they would be normally when inside of the instrument, they will both be immersed in a glass of water at room temperature, which causes no change in the reading on the instrument, as shown in Fig. 5. The temperature of the cold end will then be lowered to 32 degrees Fahr. by immersing it in a glass of ice water, as shown in Fig. 6, and the indicating arm will move up the scale showing an error due to the cooling of the cold end to 32 degrees Fahr.

In Fig. 7, both the cold end and the compensator are immersed in the glass of 32 degrees Fahr. ice water and the indicating pointer on the instrument will return instantly to its original correct position 212 de-

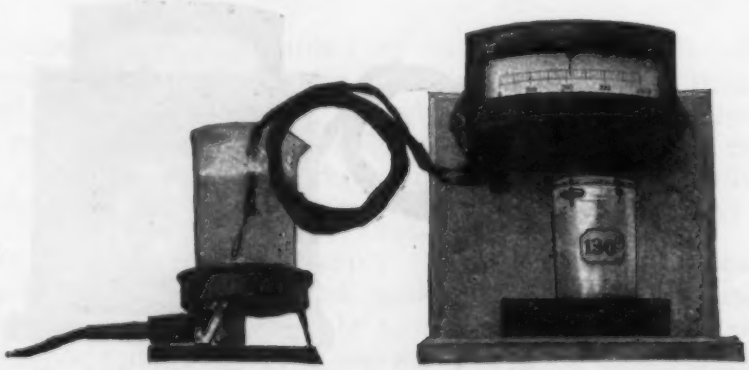


FIG. 9—HOT END IMMERSED IN BOILING WATER AND COLD END AND COMPENSATOR IMMERSED IN WATER AT 130 DEGREES FAHR.

grees Fahr. on scale, showing that the cold end temperature is eliminated when both cold end and compensator are lowered in temperature.

Having shown that the error caused by lowering the temperature of the cold end when no compensation is provided and how the error is automatically compensated for, we will now show the effect of raising the temperature of the cold end. In Fig. 8 the cold end is shown immersed in a glass of water at 130 degrees Fahr. and the indicating pointer moves down the scale, showing the error due to heating the cold end alone to 130 degrees Fahr. In Fig. 9 both the cold end and the compensator are immersed in the glass of water at 130 degrees Fahr. and the indicating pointer will immediately return to its original correct position of 212 degrees Fahr. on the scale, showing that the cold end temperature error is eliminated when both the cold end and the compensator are raised in temperature.

Thus it will be noted that the effect of the automatic cold end spiral is to neutralize the errors caused by variations of temperature of the cold end of the thermocouple, and that it automatically compensates for atmospheric changes in temperature from 32 to 130 degrees Fahr. Both the cold end of the thermocouple and the compensator are located within the instrument and in practice they are both subjected to the same rise or fall of the room temperature, and the instrument will therefore show the true temperature independent of any atmospheric temperature changes where the instrument is located.

This method of automatically compensating avoids the necessity of making corrections or employing expensive and complicated devices for artificially holding the cold end of the thermocouple at a constant temperature. This compensator can be applied readily to millivoltmeter types and all ranges of thermoelectric pyrometers, either indicating, recording or controlling, to secure accurate results even under difficult conditions ordinarily found in industrial plants. Many of these instruments have been equipped with this compensator and put into successful service.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

REPORTED FROM THE ROCKFORD CHAPTER

QUESTION NO. 1 Has anyone present at this meeting had any experience demonstrating the beneficial influence of heat treating in connection with automobile and similar parts compared with untreated alloy steel?

ANSWER. By Charles Cotta of the Cotta Gear Co., Rockford, Ill. The drive shaft in a 5-ton truck measuring about 2⅛-inch in diameter gave satisfactory service for an indefinite period. When it was changed to a 7-ton truck the change made it necessary to reduce the cross section of the shaft by about ⅛ inch. The shaft failed after a short period of service, and when the causes of the failure were investigated, it was found that the material used was a 3½ per cent nickel steel untreated. The description of this material answered S.A.E. Specification 2335. In this instance, as is well known, the material has an ultimate strength of about 50,000 pounds per square inch. If this material had been heat treated its physical properties would have been as high, which would have provided a large margin of safety, the reduction in diameter notwithstanding. Events later on proved this assumption to be correct.

QUESTION NO. 2. What are the respective merits of carbonizing under high heat for a short time or low heat for a long time, and why is sometimes one employed and why the other?

ANSWER. By R. M. Smith, Mechanics Machine Co., Rockford, Ill. The advantage of high carbonizing heat is that it is a time saver. Its disadvantages are: Increased cost of maintenance for furnaces, coarsening of the structure of the parts being carbonized, and inferior wearing qualities in the case thus obtained. Where no other requirements than mere hardness are to be met, higher heats, such as above 1700 degrees Fahr. are permissible and from a production standpoint perhaps warranted, but never recommended by the conscientious heat treater. Lower temperatures will require longer time and are in consequence more expensive for obtaining a case of equal thickness. However, in employing lower temperature the carbon contents of the case shades gradually into the core, and in consequence a case of a much higher wearing quality is obtained. Further, it has been observed that the case from lower carbonizing temperatures, that is from 1600 to 1700 degrees Fahr., shows less tendency to separate from the core underneath.

QUESTION NO. 3. Why do green castings warp during and after machining, and what can be done to overcome it?

ANSWER. By C. Craine, Mattison Machine Works, Rockford, Ill. During the war large numbers of fixtures and gages with cast iron bases

or frames were made which had to be turned out hurriedly and therefore could not be given the customary ageing, which consists of exposing them to the open air under varying weather conditions from six months to one year. We noticed considerable warpage during and after machining and remedied this disturbance by placing the castings, which were of the regular gray iron type, into a furnace, maintaining a temperature varying from 600 to 900 degrees Fahr. for a period of 12 to 18 hours and cooling them with the furnace. In most cases this procedure was sufficient to overcome the trouble. During further machining operations this was found not to be the case so a second treatment of the same temperature and equal time was applied, for example, from 12 to 24 hours was added. In extreme cases when even two treatments did not prove sufficient, the castings were hammered and exposed for a third time to a temperature from 600 to 900 degrees Fahr. and a similar period of time as before. This did away entirely with all distortion and I am unable to relate one case where further disturbance or changes in the finished gage were observed.

QUESTION NO. 4. One more question was asked pertaining to the rehardening of a die and a result of very short life, the ratio being about 10 to 1 compared with the first hardening. Several explanations were offered: 1. Insufficient annealing previous to hardening; 2. insufficient removal of stock from the old surface; 3. insufficient allowance of room around the form for flash; and 4. improper hardening. For proper hardening the suggestion was made to place the die block into the furnace, running at a temperature of 500 degrees Fahr. and then to allow one hour of time for every inch of thickness of the block until it was heated to 1500 degrees Fahr. For instance, if the die measures 7 inches high by 10 inches wide by 16 inches long, the total time for reaching the hardening temperature would be seven hours. An addition of two hours should be made for equalizing the temperature throughout, so that the total time of being in the furnace and previous to quenching would be nine hours. As proof for the correctness of this method, the experience of a large drop forging department was related to the effect that out of about one thousand die blocks only three were lost on account of cracking.

QUESTION NO. 5. *What is needle bar stock?*

QUESTION NO. 6. *Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?*

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

CARBONIZING

NITROGEN IN CARBURIZED STEELS. By W. E. Ruder and G. R. Brophy, *Chemical and Metallurgical Engineering*, Vol. 25, Page 867.

Nitrogen as well as carbon is responsible for the hardening obtained on carbonizing. Nitrogen may be detected by the use of Stead's reagent. The effect of nitrogenous and nitrogen-free carbonizers on pure iron was investigated as was the effect of nitrogenous carbonizers on all of the common alloy steels. Nitrogen was found to act similarly to carbon. No actual nitrogen determinations were made, the results all being based on metallographic inspection.

EFFECT OF HEAT TREATMENT ON PHYSICAL PROPERTIES

ARTIFICIAL SEASONING OF STEELS. By H. J. French, *American Machinist*, Vol. 55, Page 768.

It has been known for some time that steel after certain heat treatments underwent dimensional and thermal changes at room temperatures. Little quantitative data, however, is at present available. Experiments were undertaken at the Bureau of Standards on five classes of steels, including, carbon, chrome and manganese steels. The steels were made up into gage blocks given various heat treatments and finished, after which they were tested at definite time intervals for dimensional and hardness changes. The results are presented in tabular form. Th high chrome and the plain carbon steels were found to be unsatisfactory as gage material. An adequate theory explaining the dimensional and thermal changes is as yet wanting.

A BIBLIOGRAPHY AND ABSTRACTS OF CHROMIUM STEELS. By F. P. Zimmerli, *Chemical and Metallurgical Engineering*, Vol 25, Page 837.

The principal papers on chromium and chromium alloy steels published during the period 1798 to 1919 are given with a brief summary of their scope.

A STUDY OF IMPACT TESTS ON CAST STEEL. By F. C. Langenburg, *The Iron Trade Review*, Vol. LXIX, Page 1145.

The influence of varying amounts of phosphorus, carbon and manganese and the influence of varying heat treatments on the Charpy impact value and on the tensile properties of steel were studied. From the tests it may be concluded that (a) varying the phosphorus from 0.043 to 0.075 per cent has little effect on the tensile properties but reduces the Charpy impact value by over 50 per cent; (b) keeping the carbon below 0.30 per cent and the manganese below 1.30 per cent appreciably increases the impact value; and (c) water quenching steel castings noticeably improves the impact resisting qualities. For the sake of comparison a table is given showing the effect on the tensile properties and Charpy values of forged steel obtained by varying the composition and the heat treatment of this stock.

IMPACT PROPERTIES OF VARIOUS STEELS. By F. C. Langenburg, *Chemical and Metallurgical Engineering*, Vol. 25, Page 910.

A study of the Charpy values obtained on centrifugally cast steel cylinders is described in detail. The other data given is the same as that covered in the article appearing in *The Iron Trade Review*.

ENAMELED STEEL

ENAMEL STEEL MANUFACTURE. By C. H. Jones, *Chemical and Metallurgical Engineering*, Vol. 25, Page 883.

A description of the plant and equipment of the Pfaudler Co., Rochester, N. Y., is given.

ENAMEL-LINED APPARATUS. By C. H. Jones, *Chemical and Metallurgical Engineering*, Vol. 25, Page 927.

A description of the plant and products of the Elyria Enamel Products Co., Elyria, O., is given.

MAGNETIC TESTING

MAGNETIC SURVEYS OF RAILROAD RAILS, Anonymous, *Iron Age*, Vol. 108, Page 1271.

Little that is new has been developed since the publication of Dr. P. H. Dudley's paper before the American Society for Testing Materials two years ago. It has been found possible to differentiate positively between ductile and brittle rails. The beneficial effect of reheating before the final rolling of the rail has been demonstrated. Many magnetically tested rails have been put in service, but it is yet to early to draw any conclusions from their performance.

MAGNETIC ANALYSIS OF STEEL. By R. L. Sanford, *American Machinist*, Vol. 55, Page 836.

A brief description of the fundamental principles underlying magnetic testing is given and some of the outfits used are shown. Attention is called to the fact that if a specimen is mechanically nonuniform, magnetic nonuniformity will always be found but that magnetic nonuniformity does not always indicate mechanical nonuniformity. Considerable additional research is still necessary before this method of testing may be generally applied.

METALLOGRAPHY AND HARDNESS THEORY

CONTRAST ETCHING FOR METALLOGRAPHIC SPECIMENS. By H. S. Rawdon and Marjorie G. Lorentz, *Chemical and Metallurgical Engigneering*, Vol. 25, Page 915.

The use of hydrogen sulphide followed by silver nitrate as a contrast etch for brasses and bronzes is described. In some bronzes it was found advantageous to use the silver nitrate first and then the hydrogen sulphide. Several photomicrographs are shown.

METALLOGRAPHIC TESTING. Bureau of Standards, Circular 42, 2nd Edition.

The circular discusses briefly the conditions which affect the properties of metals under the following divisions: Microscopy and structure, thermal analysis and heat treatment, mechanical working of metals, chemical and metallurgical factors and melting conditions. The conditions under which metallographic tests are made at the Bureau of Standards are explained.

THE ORIGIN OF STRAINS IN HEAT TREATING. By W. Tafel, *Stahl und Eisen*, Vol. 41, Page 1321.

The volume changes taking place on heating and cooling steel as various roles are followed. The opinions of the author and of Heyn on the causes of hardening are set forth. No original data is given.

THE STUCTURE AND RELATED PROPERTIES OF METALS. Bureau of Standards, Circular 113.

This circular supplements the one on "Metallographic Testing." The development of structure in alloys is first discussed and a list of etching reagents is given together with information on their purpose and use. The effect of composition on structure is considered. The changes due to changes in composition, heat treatment, etc., are discussed. The effect of structure on the physical and chemical properties is covered and typical applications of the miscroscopic study of metals are cited.

NEW MATERIALS

THE FUTURE OF STAINLESS STEEL, Anonymous, *Engineering*, Vol. CXXXII, Page 447.

The use of high chromium steel as turbine blades and pump rams is discussed.

GENELITE: AN IMPROVED BEARING ALLOY. By E. G. Gilson, *General Electric Review*, Vol. XXIV, Page 949.

A new bearing material is described having a compressive strength of 50,000 pounds

per square inch. It is made up of bronze containing many fine particles of graphite. Bearings are made up from the powdered bronze by pressure.

WELDING

THE SCIENCE OF ELECTRIC WELDING. By W. E. Ruder, *Journal of the Franklin Institute*, Vol. 192, Page 561.

A discussion of the rise and development of welding is given. The various types of welds are taken up and the structure of the finished welds is shown by numerous photomicrographs. Equipment is discussed in very general terms. The article is of a nontechnical nature and no new data is submitted.

WELDING IN THE DROP FORGE SHOP. By J. H. G. William, *Forging and Heat Treating*, Vol. 7, Page 453.

This paper is restricted to the electric resistance method of welding by which two pieces of metal are held together while an electric current is passed through them sufficient to develop heat enough at their point of contact to produce fusion. Welds were made on a large number of ¼ and ⅜-inch round stock. The physical properties of these welded rods were determined and are presented in tables. In no case was the strength of the weld less than one-third of the strength of the stock.

THE FUSION WELDING OF STEEL. By S. W. Miller, presented at the November meeting of the American Iron and Steel Institute.

Three types of fusion welding are at present in use, (a) gas welding, (b) arc welding, and (c) thermit welding. The present paper is confined to the two former types. Low carbon steel rods (carbon 0.05 to 0.16 per cent) are used for filling in the weld and in the case of the arc weld it has been found advantageous to use rods covered with a slag forming material. Nickel steel welding rods have been found to be superior to the plain carbon steel rods. Welds are to a large extent dependent upon the skill of the welder. The welder should be given proper training and his work should be tested at regular intervals. Welds are in general weak to shock and alternating stresses and the tests used are described. A considerable amount of research is still needed before great uniformity may be expected in welded material.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

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HAYNES, J. K., (M-7)—from 18 West St., Waterloo, N. Y. to The Engineering Experiment Station, Annapolis, Md.
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ZIMMERLI, F. P., (M-1)—from 5106 Woodward Ave. to 459 Hancock W. Detroit, Mich.

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GORHAM, WM. R., 53 Aza Kominato, Kitagate Machi Juniten, Jokoham, Japan.
HANCOCK, GEO., M., Union Charcoal & Chemical Co., Rochester, N. Y.
HOWE, H. A., Standard Heat Treating Co., 1971 Guoin St., Detroit, Mich.
HUNTER, GEO. C., Hotel Huron, Cleveland, O.
LAWRENCE, A. H. M., 511 West Grove, Ontario, Cal.
LEININGER, J. R., 308 West Packer Ave., Bethlehem, Pa.
LIVINGSTON, EDDIE, (M-4), 1208 S. Seventh St., St. Louis, Mo.
JARDINE, J. J., Y. M. C. A., Syracuse, N. Y.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Wednesday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri Cities—First Thursday following first Monday.

Washington—Second Friday.

ROCKFORD CHAPTER

FOLLOWING is a report from the *Rockford Morning Star* of Dec. 13 which quite well presents an account of the initial meeting of the Rockford Chapter at Rockford, Ill., Dec. 12:

"Nearly 100 steel treaters of Rockford gathered last night at the Nelson hotel for the first monthly banquet and business session of the Rockford Chapter of the American Society for Steel Treating. A good dinner and an excellent address were followed by a general discussion of problems confronting local workers in steel.

"William H. Eisenman, Cleveland, O., National Secretary of the organization, delivered a splendid talk on steel treating. His remarks were filled with humorous anecdotes which kept his audience smiling while he drove home the points of his discussion.

"Steel treating, said Mr. Eisenman, began with Adam and Eve, for the race was young when the discovery of steel was made, probably by the building of fires on mineral sands. This, said the speaker, would have led to the discovery of chunks of metal in the ashes, formed by the heat. He recited in detail the various steps in which progress in the use of steel and in the treating of it to obtain varying degrees of hardness was made.

"Ancient writers were quoted by Mr. Eisenman to show that the knowledge of heat treatment existed at the dawn of civilization.

"Superstitions that survived for centuries, becoming 'trade secrets' were gone into in detail. Certain waters were supposed to be more effective in quenching the heated metal and every manufacturer of steel in the early days of the industry had his own special brand of liquid for this purpose—one mixing garlic with brandy, another using the blood of slaves, and others introducing their own odd mixtures. One medieval treatise on heat treatment asserted in connection with the blood method that 'red-headed boys were advocated for the finest grades of steel.'

"Getting down to the present time, the speaker told of numerous modern methods of doing the work, some of which show a great similarity to

those of the ancients. He spoke of visiting many American plants and asserted that the idea of secrecy in methods was rapidly giving place to a desire on the part of steel treaters to exchange ideas for the improvement of the science.

"This spirit of co-operation, declared Mr. Eisenman, forms the basis of the American Society for Steel Treating, a society which, he said, is not a money-making proposition, but purely an educational organization. Every question that puzzles steel treaters is taken up by the society and a solution found. Members present their individual problems, the solution of which the society undertakes. Papers on the various technicalities of steel treating which are read at the monthly meetings of the 32 chapters are published every month in the society's TRANSACTIONS, a 160-page book which is sent free to every member.

"Horace H. Clark, Chicago, acting chairman of the Chicago chapter of the society, was present and in a short address congratulated the local men for the large number present, which, he said, was proportionately much greater than ordinarily enjoyed by new chapters.

" 'Instead,' said Mr. Clark, 'of coming out here to tell you men how to organize, I find I am getting pointers that I shall be glad to take back to our Chicago chapter. I want to find out how your committee did in a few weeks what it has taken most of us months to do in the way of getting organized.'

"Of those who sat down to the dinner last night, 31 were members of the local chapter. Before the program was over 26 additional applications for membership were in the hands of the secretary and a number of others were promised. There are about 150 men in Rockford interested in steel treating and thus eligible for membership.

"Otto F. Muehlemeyer, chairman of the Rockford chapter, acted as toastmaster last night and made the address of welcome to the guests. Other officers of the chapter are: Oscar Harrison, vice chairman; R. M. Smith, secretary-treasurer; and Charles Cotta, John B. Frederick, C. R. Crain and A. H. Memiring, directors.

"Charter members of the chapter, all of whom were in attendance at the dinner last night, were C. D. Barrand, R. G. Burmeister, J. J. Burns, Charles Cotta, C. R. Crain, John Dahleen, John B. Frederick, E. M. Greenslit, James F. Gorrell, O. H. Harrison, Will Hickox, George J. Johnson, Edwin Knapp, P. H. Landis, G. W. McKee, A. H. Memiring, A. M. Monks, O. T. Muehlemeyer, George Nash, J. A. Nelson, Otto Olson, J. L. Rossier, R. M. Smith, A. W. Swanson, W. G. Thomas, C. V. White, H. L. Waisner and W. K. Young."

NORTHWEST CHAPTER

The November meeting of the Chapter was held on Nov. 28 at the Manufacturers' Club, Minneapolis. H. K. Briggs, Minneapolis Electric Steel Castings Co., presented a paper on "Instruments and Apparatus, Pyrometry, Microscopy, Physical Testing and Furnaces," which was illustrated by lantern slides.

At the meeting of the Chapter Wednesday evening, Dec. 7, the members had the pleasure of meeting F. P. Gilligan, National President of the Society. Mr. Gilligan is making a tour of the country visiting 32 local chapters of the Society. He was very favorably impressed with the work being done by the local chapter, which is known as the Steel Treaters'

Section of the Manufacturers' Club, and was enthusiastic about the educational course being conducted for the benefit of those who are interested in studying the fundamentals of metallurgy and steel treating. Mr. Gilligan left Thursday, Dec. 8, to visit the St. Louis Chapter.

NEW HAVEN CHAPTER

The New Haven Chapter held a very interesting meeting in the Chamber of Commerce room, New Haven, on Friday evening, Nov. 18. Due to the miserable weather conditions only about 50 were in attendance. The meeting itself was enthusiastic and both papers very interesting. William R. Bennett, president of the Bennett Heat Treating Co., Elmwood, Conn., gave a practical paper entitled, "Atmospheric Conditions in a Heat Treating Furnace and How to Control the Same."

The other paper was given by N. B. Hoffman, chemist and metallurgist, Colonial Steel Co., Pittsburgh, Pa., and was entitled, "Ghost Lines and Grain Elongation in Hot-Rolled and Cold-Drawn Iron Wire and Tool Steel."

One of the best meetings held by the local chapter took place in the assembly room of the New Haven Gas Light Co. on Dec. 21. James Black, foreman of heat treating, Geometric Tool Co., Westville, Conn., presented an interesting paper on "The Importance of Uniformity in Heat Treating." Dr. Paul C. Doerr, metallurgical engineer, Springfield, Mass., spoke on "Principles of Carburizing, Quenching and Tempering." These two papers appealed to both the technical and practical men, and in consequence there was a very large attendance. A lively discussion on both subjects proved of much value as well as the interesting questions taken from the question box. After the meeting a smoker was held followed by refreshments and all of the members enjoyed the good fellowship of the New Haven Chapter.

The next meeting will be held Jan. 25 at Yale University.

PITTSBURGH CHAPTER

Prof. H. F. Moore, University of Illinois, Urbana, Ill., delivered an address on "The Fatigue of Metals," at the meeting of the Pittsburgh Chapter on Dec. 6, at the Hotel Chatham. His address which was illustrated with motion pictures and lantern slides was based on the reports of an investigation into such phenomena conducted by himself and Prof. J. B. Kommers, also of the university, in co-operation with the National Research Council, the Engineering Foundation and the General Electric Co. Professor Moore discussed at length the phenomena of the fatigue of metals and concluded with a review of the progress made by the investigation up to date. The meeting was attended by probably one hundred members and their guests.

A meeting of the Council was held on Dec. 19 to discuss plans for the spring sectional meeting of the National Society in Pittsburgh in May.

LEHIGH VALLEY CHAPTER

Geographically located in one of the greatest industrial centers of the United States and perhaps of the world, the Lehigh Valley Chapter is spurred on to maintain an equal footing among the valleys' technical societies. That they are capable of doing it was most evident when on Nov. 28, 130 members and guests braved one of the worst storms experienced in the valley for a long time to attend a dinner-meeting given

National President F. P. Gilligan, of the Society at Kurtz' restaurant, Bethlehem, Pa.

Dinner was served promptly at 7 o'clock in the banquet room of the famous restaurant. Following the dinner and prior to the introduction of President Gilligan, 15 minutes was devoted to mirth and joviality wherein those present were given an opportunity to become better acquainted. It was at this time that the members were surprised by an orchestra composed of five artists, members of the chapter. With the able assistance of song leader "Bill" Laury the orchestra held the enthusiasm at highest pitch.

President Gilligan, upon being introduced, addressed the meeting on "Quality First." Mr. Gilligan held the closest attention as he forcefully impressed the value and importance of his subject. The talk was illustrated with slides. Many photographs as well as photomicrographs were shown of failures which occurred in tools and machine parts due to faulty material, improper design, and carelessness or the short circuiting of the heat treating. Throughout his entire talk Mr. Gilligan laid great stress upon the present day tendency to place production and not quality first.

Among the guests present were T. D. Lynch, research engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.; W. Williams, metallurgist, Billings & Spencer Co., Hartford, Conn.; and W. O. Hearsey, division superintendent, Bethlehem Steel Co., and president Lehigh Valley Engineers' club. Each in turn spoke very highly of the opportunities which the society offered to those using steel or steel products.

There was no December meeting of the chapter. The committee announces that the next meeting will be the third of the series on "The Manufacture, Treating and Testing of Steel," and will be held in the Public Library auditorium, Easton, Pa., Jan. 9, 1922. This meeting will be addressed by Messrs. W. Cutter and W. G. Walton, of The Bethlehem Steel Co., on "Rolling Mill and Foundry Practice".

PROVIDENCE CHAPTER

W. C. Peterson, metallurgist of the Atlas Crucible Steel Co., spoke before the Rhode Island chapter at Providence on Wednesday, Nov. 30. This proved to be an excellent meeting due to the fact that Mr. Peterson handled his subject "Tool Steel and Its Heat Treatment" in such an acceptable manner. The subject dealt particularly with treatment of dies, reamers, broaches, files; also preheating and its different phases, machining tool steels, and the value of fillets.

NEW YORK CHAPTER

A very enthusiastic and well attended meeting of the New York Chapter was held in the Engineering Societies building, Wednesday, Nov. 16. Over one hundred members and guests were present, and they enjoyed a very interesting address by T. Holland Nelson, works manager of the H. Disston & Sons, Philadelphia, Pa., who gave an illustrated talk on crucible steel making as practiced in England and in America. Mr. Nelson spoke with the authority which comes from many years of experience, both in his native town of Sheffield and in various American works.

Previous to the paper of the meeting, E. E. Thum, associate editor *Chemical & Metallurgical Engineering*, New York, in reviewing current events of interest to metallurgists, called attention to recent publications on the investigation of metallic structure by X-rays, and a modern adapta-

tion of forge practice called "hammer welding", used for making large welded boilers, pressure containers, and pipe.

The program committee feels very much gratified in the response of the local membership thus far this year, and takes it as an indication that their plans for the year are along the right lines. These consist of a series of evenings, each of which will cover some phase of the heat treaters' work, and be handled by an expert in that particular line. Next month the chapter will entertain National President Gilligan, who will speak on the subject "What Happens to a Piece of Steel When You Heat and Quench It?"

The practical talks for 1922 are as follows:

JANUARY:—Annealing and tempering machine and tool steels.
FEBRUARY:—Case hardening (carburizing and subsequent heat treatment). Ways of doing it, and what it does to a piece of steel.
MARCH:—Treatment of high speed steel.
APRIL:—Hardening room troubles, shrinkage, warpage and scaling.
MAY:—Up-to-date hardening room equipment, furnaces, pyrometers and auxiliaries.
JUNE:—Spotting the reason for failures in service. Practical uses for microscopes and physical testing machines.
Added Attraction:—Current events, a 10-minute talk at each meeting on recently published items of interest to heat treaters. Come to the meetings and get into the discussions of the topic presented.

CLEVELAND CHAPTER

The November meeting of the chapter was held at the Engineering Society's room, Hotel Winton, Friday evening, Nov. 25, and consisted of discussion of questions submitted at the previous meeting. Each question was assigned to a member to open the discussion. The questions submitted were as follows: "Heat Treatment of 3-Inch Forgings to Obtain Certain Physical Properties", by Ray T. Bayless; "Ageing and Heat Treatment of Cast Iron", by Robert Archer; "Effect of Silicon in Tool Steel", by J. V. Emmons; "Effect of Pickling" and "Carburizing High Speed Steel", by W. S. Bidle. About 65 members were in attendance at the dinner and over 30 members participated in the interesting discussions.

The December meeting was held at the same place on Dec. 9 and was addressed by Prof. H. F. Moore, of the University of Illinois. Prof. Moore's talk on the "Fatigue of Metals" was illustrated by slides and moving pictures, and proved to be one of the best meetings from the point of attendance, 200 being present, that the chapter has held this year.

SYRACUSE CHAPTER

The chapter had a well attended meeting in the Yates hotel on Friday, Dec. 2. D. D. Ormsby, chief engineer, Brown Lipe-Chapin Co., Syracuse, N. Y., read a paper, "Automobile Rear Axle Gears". After a terse description of the various systems of gears he dwelt on the problems that confront the designer of gears for automobiles, describing carefully the necessity of meeting conditions induced by automotive design. He mentioned in passing the various type of materials used, the machines to produce the gears and finally the troubles caused by the hardening process. The audience, made up largely of men from various other gear plants of the city, questioned Mr. Ormsby closely on best practices and safeguards to insure a good product.

Mr. Howell's paper, "The Designing of Tools," was well received since he addressed an audience that had experienced difficulties in hard-

ening tools of poor design. His paper covered tools, jigs and fixtures usually found in a gear plant. Especial interest was shown by the steel men present in the matter of broaching. This is a problem that bothers, and is a hard operation to perform on account of the size and shape of holes to be broached and the condition of the material.

HARTFORD CHAPTER

The regular December meeting of the Hartford Chapter was held on Dec. 8 at the assembly hall of the Hartford Y. M. C. A. The audience numbered 125, of whom 35 were members and 90 were nonmembers. The meeting started with musical entertainment provided by Mr. Hathaway's entertainment committee. Then Mr. Rockwell introduced new members and guests to the meeting. Mr. Graham, of the New York Chapter, announced the plan for sectional meetings during the winter, with particular reference to the New York meeting in March, and called for volunteers to present papers at that meeting.

George P. Moore, metallurgist of the Wallace Barnes Co., Bristol, Conn., read a paper dealing with design, materials, heat treatment, and inspection of springs, as carried out in that plant. He also exhibited numerous samples of springs of various types, and failures to which these springs were subject. Owing to an accident occurring to the car in which he drove to the meeting, it was necessary to abandon the greater part of the samples on the road, the party being forced to transfer to another already crowded car. His paper was very interesting and valuable, in that it covered the entire manufacture from the design to the finished product. The paper will be available for publication, and the chapter believes that it would be a valuable addition to the TRANSACTIONS. Many of the audience announced their desire to acquire a copy of the paper, and it is probable that a limited number of type-written copies will be made for distribution within the chapter. After Mr. Moore's paper was read, open discussion took place, and many questions relating to specific uses were discussed.

The final feature of the meeting was a description of a somewhat common effect observed in the heat treatment of high speed steel. After hardening, the high speed tools exhibited by Mr. d'Arcambal, showed a file-hard surface. When the tool was fractured, however, the fractured surface could be filed easily. Examination of the tool, which was not over 0.25 inch thick, showed that it possessed a thin hardened skin, having a thickness of only 0.002 or 0.003 inch, the remaining interior portion being quite soft to the file. Tools of this sort appeared to be properly hardened when tested with the file, but after the first grinding in service, were found to be useless. In the discussion that followed many opinions were offered as to the reason for this effect. It developed that this effect had been noticed only in the 18 per cent tungsten type of high speed steels, and then only when the carbon content was in the range of 0.50 to 0.60 per cent. The effect is undoubtedly due to the relatively low carbon content. Failures of this sort can be guarded against only by careful inspection and chemical analysis of the bar stock before shaping into tools.

Mr. d'Arcambal also told of experiments he had made to determine the effect of furnace temperature on the rate of heating of a cold tool placed in the furnace. He gave as examples the following: Two pieces of steel of the same shape and size were placed at the same time in two

similar furnaces, one of which was running at 1400 degrees Fahr. and the other at 1800 degrees Fahr. It would seem natural for the piece placed in the 1400 degree furnace to reach the furnace temperature first, but as a matter of fact, the 1800 degree piece was first. The difference in temperature gradient, also the proximity of the 1400 degree heat to the critical point of the steel play a part in this paradox. Similar tests have been described recently in the metallurgical press, in which the same results were obtained.

The subject of the January meeting was announced at the close of the meeting. H. J. French, of the Bureau of Standards, Washington, will speak on the work and equipment of the bureau. His talk will be illustrated by lantern slides and possibly by moving pictures. He should be able to interest all by a description of some of the problems investigated and solved by the bureau.

Unless otherwise announced in the monthly poster notices, the regular monthly meetings of the chapter will be held on the Thursday nearest the 10th of each month, at 7:45 p. m., in Jewell Hall, Y. M. C. A., Hartford.

The date and program for each meeting is as follows:

JANUARY 5:—"The Relation of the Bureau of Standards to Industry," by H. J. French, Bureau of Standards, Washington.

FEBRUARY 9:—"High Speed Steel," by A. H. d'Arcambal, Pratt & Whitney Co., Hartford, Conn.

MARCH 10:—Heat Treatment Contest. Everyone is invited to compete for the prize.

APRIL 13:—"The Characteristics of Tool and Alloy Steels," by Dr. John A. Mathews, President Crucible Steel Co., Pittsburgh.

APRIL 29:—9:00 a. m., Inspection of New Departure Co. Plant, Bristol, Conn., Courtesy of the New Departure Co. All New England Chapters of American Society for Steel Treating and American Society of Mechanical Engineers are invited.

MAY 11:—"The Inspection and Heat Treatment of Steel," by J. J. Curran, The Henry Souther Engineering Co., Hartford, Conn.

JUNE 8:—Annual Banquet. Speakers to be announced later.

In addition to the subjects announced above, some time will be devoted each evening to:

1. "Question Box;" 2. Short reviews from current literature on steel treating and equipment; and 3. Some unique heat treatment effects observed by members.

WASHINGTON CHAPTER

On Friday Dec. 16, the Washington Chapter was addressed by N. B. Hoffman, of the Colonial Steel Co., his subject being "The Hot Rolling and Cold Drawing of Low Carbon Steel Wire." Inasmuch as rods and wire find many applications in general construction as well as special application in ordnance, aircraft and naval construction, the paper proved of special interest to the chapter. The speaker has had extensive experience in the manufacture of these products. The effect of composition, rolling or drawing, heat treatment; the causes of flaws in wire products and the relation between these flaws and the condition of the material were discussed by Mr. Hoffman.

INDIANAPOLIS CHAPTER

The Indianapolis Chapter had a very interesting paper presented on Nov. 21 by H. G. Hall, a representative of the Bristol Co., on the subject of "Cold End Compensation in Pyrometry". Mr. Hall's paper was illustrated with lantern slides and moving pictures.

The annual visit of President Gilligan occurred on Monday night, Dec. 5 when 75 members were present to attend a smoker in honor of

the President. Mr. Gilligan spoke on activities of the Society, and also presented stereopticon slides illustrating his talk, "Quality of Material and Workmanship". The meeting was considered to be one of the best ever held by the Indianapolis Chapter.

CHARLESTON CHAPTER

The Charleston Chapter had an excellent meeting at the Kanawah Hotel on Tuesday evening, Nov. 22, when the National Secretary, W. H. Eisenman was present and spoke to the members with reference to the activities of the Society. J. E. Arthur presented a paper the same evening on "Steel Melt Shop Practice". Mr. Arthur's paper produced good discussion.

The Charleston Chapter is in an excellent condition due to the active interest and co-operation of all its members. Chairman Priestley is taking a special interest in providing good speakers for the coming meetings. On Dec. 13, H. J. French, Bureau of Standards, presented an interesting paper on the work at the Bureau, while W. H. White of the local chapter presented a paper on "Sand Casting and Iron Mold Practice."

The chapter has adopted the practice of having a short paper presented by some member of the local chapter on the same evening that it has an out-of-town speaker. President Gilligan will pay his annual visit to the Charleston Chapter on Jan. 19 when the subject of "Forging Practice" will be presented by C. A. Gosztonyi. The local speakers and the dates of meetings for the coming meetings are as follows:

FEBRUARY 7:—"Heat Treatment of Carbon and Nickel Forgings and Castings," by A. F. Mitchell.
MARCH 7:—"Heat Treatment of Chrome-Nickel and Molybdenum Steels," by H. W. Fullmore.
APRIL 4:—"The Necessity of High Quality Steel for Ordnance Purposes," by C. E. Margerum.
MAY 2:—"The Chemical Laboratory and Its Relation to Shop Operations," by Harry Schagrin.
Election of New Officers.
JUNE 6:—"The Inspection of Ordnance Forgings," by J. E. Holden.

Chairman W. J. Priestley was unable to attend the first fall meeting of the Chapter but sent a communication to the members of the Chapter which was read by the secretary. His remarks were of interest and for the benefit of the Society are reproduced as follows:

September 28, 1921.

Fellow Members:—

I am exceedingly sorry not to attend tonight's meeting. I assure you that my absence is in no way indicative of my interest and enthusiasm in the welfare of the Society.

I wanted to tell you tonight what the Society stood for and what it means individually to you men who make your living in the steel industry. There has been an awakening in the entire steel industry since the war. I believe in the future, all steel makers are going to pay more attention to quality of product instead of tonnage. The automobile manufacturers have had this vividly impressed upon their product and nearly all such factories today have well equipped heat treating establishments and research laboratories where they are endeavoring to improve their product all the time.

Those of you who have been in the steel business for eight or ten years will agree with me that many steps forward have been taken in the last five years. I have in mind a steel foundry in one of the largest plants in the country which five years ago did not even have pyrometers on their furnaces for annealing castings. These furnaces were coal-fired, open-top types, and when it was suggested to the superintendent of the foundry that he had better get in a requisition for some electrical pyrometers on his furnace, he threw up his hands in horror and

became very indignant. This same man had lying out in his stock yard at that time, castings which had been made fourteen months previously, which he had been unable to pass merely on account of improper annealing. Subsequently, all these castings were annealed and at least 90 per cent of them passed test. This is only one illustration of the many instances that might be cited how people in the steel industry were groping along in the dark several years ago.

I know another instance of a government establishment which six years ago, was ordering heat treated blooms and billets, and pulling tests on the same for acceptance in spite of the fact that these blooms and billets were subsequently forged and given an annealing without any heat treatment or testing after forging. I think that a state of affairs like the two instances cited above are due to the fact that men in the shops have not been able to broaden and know what other people are doing. If there is no other benefit which men in the steel business can get from the American Society for Steel Treating, they can at least get ideas from other people who come here to talk; from discussing subjects at the meetings, and developing and drawing out their own ideas.

I also want to present to you the idea that the American Society for Steel Treating is for men in the shop as well as for technical men. The heat treatment of steel takes in such a large field, there is so much detail to it, that the co-operation and support of both the practical men in the shop, metallurgists, and heat treatment men, or supervisors, should all be combined in order to get the best results.

I also want to state that the Society is not limited to men who are employed in the heat treatment of steel alone. Melters, forgers, machinists, and all other men who make their livelihood in any branch of the steel industry are eligible to membership in this Society. Every one who is in the steel business owes a certain amount of his time to the development and upbuilding of the art or science of making steel. Everybody has an opportunity to contribute papers to the Society and I want to encourage all the members to pick out a subject and prepare a paper to be read some time. You will be surprised to find out how much benefit you will receive from the preparation of a paper. You men who think you know your own subject perfectly well, and probably do for the routine work you have to do, find when you come to put down certain facts which you know are likely to be discussed or criticized by others that you are going to go deeper into the subject than you would otherwise.

A successful steel plant which has such a variety of departments, must have each and every department functioning smoothly and without friction. The American Society for Steel Treating affords the machine shop men some insight into the problems that the steel melter, forger and heat treatment man are up against, and when he finds a defect in a forging or casting, he is not going to be so inclined to criticize and blame the other man for not being on the job, but is going to have a better understanding of the work himself and probably from an entirely different point of view, and thus he may be able to make suggestions to the heat treatment or melt shop men. The same applies to the man that forges steel made in another department than his own. I have seen in many steel plants too much "buck passing." I think this comes not so much from a malicious spirit or "I don't care" spirit as it does from the fact that men in the various departments do not know enough about the other man's problems. This Society affords men a broader vision and a better outlook in their entire work.

The American Society for Steel Treating affords men an opportunity to advance and improve their education. No man wants to stand still. Every one of you has an ambition to go ahead. When you belong to this Society, you receive papers prepared by men at other chapters. By careful reading of the papers, attending meetings of your own chapter and entering into discussions, you will soon find your vision broadening and you will get yourself in line for positions of greater responsibility.

I wish also to impress upon you that as a member of the Society, you belong to one of the strongest, most aggressive and rapidly growing societies of the country today. The Society now is about two years old and has a total membership of 3200 men. This membership is made up of the most prominent steel men in the country who are leaders in other major metallurgical and technical societies The National Society is directing its efforts along well defined and practical lines. I understand it was decided at the National Convention recently held in Indianapolis, to establish a research committee which would carry on in certain laboratories practicable lines of research which have never heretofore been undertaken.

At this first meeting of this season, I desire to have you hear what your three

representatives learned at the Indianapolis convention. Your committee on meetings and papers have made arrangements for a prominent out-of-town speaker for the next meeting.

We now have about 50 members in the Charleston Chapter. We have a great deal of talent in this Chapter already—but there are many more men in this community whom, I feel would make valuable additions to our Society and I hope that they will take kindly to our invitations and come with us. I want every present member of the Society to consider himself a member of the Membership Committee, and bring his friends around to some of the succeeding meetings. I want to impress upon you that Charleston Chapter will be a great success, only, as you men make it. I also wish to impress upon you that all you get out of it will depend upon the interest and the work you do in the Society. Don't feel that because you are not a literary genius that you cannot write a good paper. We want you to come to all the meetings regularly and enter into the discussions which take place after the reading of papers.

BOSTON CHAPTER

Through the courtesy of the Massachusetts Institute of Technology, the Boston Chapter held its initial laboratory meeting at the institute on the evening of Dec. 9. A large number attended. Irving H. Cowdrey, chairman, presided and introduced Harrison W. Hayward, professor of materials of engineering at the institute. For the benefit of those not familiar with a testing materials laboratory, Professor Hayward explained first its functions—routine, research, testing of structural steel, and just what constituted each kind of work under these headings. This was followed by an explanation of the relation of the laboratory to industry, a lesson in the proper use of terms used in connection with laboratory work, and finally, useful information regarding the preparation of specimens to be presented for laboratory testing.

Following Professor Hayward's remarks, the members visited various laboratory divisions of the institute, and with the aid of laboratory result sheets, witnessed tests made on a large number of specimens furnished by various steel companies. For the institute, A. C. Fales and I. N. Zavarine conducted tests in the heat treating laboratory; Victor Homerberg in the metallographic laboratory; R. G. Adams in the autographic testing, hardness and shock testing laboratory; and C. A. Chayne and E. M. Brickett in the commercial testing laboratory. In the shock tests, Mr. Adams was assisted by Mr. Cowdrey. An open discussion followed the testing, many questions being asked and answered by Mr. Cowdrey, and those in charge of the testing machines. Members attending agreed the meeting was the most interesting held by the Boston chapter and an effort will be made to hold another meeting at the institute.

CHICAGO CHAPTER

At its November meeting held at the City Club, the Chicago Chapter had a question box in which a large number of members took a very active part. There was much interest displayed throughout the evening and little hesitancy in asking and answering questions.

The December meeting was held at the City Club on Thursday evening, Dec. 8. The speaker was Dr. Zay Jeffries, of Cleveland. Dr. Jeffries' paper on the "New Theory of Hardening" was illustrated by lantern slides and proved one of the most interesting papers presented before the local chapter. This was due to several reasons among which are: Dr. Jeffries' complete mastery of the subject, his pleasing and entertaining presentation of the subject matter, as well as many apt illustrations Dr. Jeffries gave in order to assist those present in visual-

izing the points under consideration. The discussion following the presentation of the paper was productive of further interest in his paper.

ST. LOUIS CHAPTER

The December meeting of the St. Louis Chapter was held at the American Annex Hotel on Dec. 9. President F. P. Gilligan spoke on "Quality of Material and Workmanship", and by the able presentation of his paper provided a very valuable evening for those in attendance. President Gilligan's paper was well received. The meeting was very successful from the time the dinner started at 7 p. m. to the close of the executive meeting at 11 o'clock.

SOUTH BEND CHAPTER

The South Bend Chapter held its meeting on Dec. 13 at 8 p. m., in the Studebaker Recreation building. Several short discussions were given covering different subjects, and these were followed by general discussion of the subjects presented. Refreshments were served.

ROCHESTER CHAPTER

The Rochester Chapter held its meeting on Wednesday, Dec. 14, at 8 p. m. in the Rochester Engineering Society club rooms. The chairman of the Chapter, L. K. Marshall, presented a paper entitled "Tool Steel Manipulation". The United States Bureau of Mines loaned the chapter two highly interesting and instructive films on "The Story of Abrasives" and "The Story of Rock Drilling".

DETROIT CHAPTER

The Detroit Chapter held its meeting on Nov. 25 at the Board of Commerce at 8 o'clock. James Schemerhorn presented a paper on "The Hearth and the Home". There were about 100 in attendance. A membership drive was inaugurated at this meeting.

The December meeting of the Chapter was held on Dec. 15 at the Board of Commerce. J. M. Watson, metallurgist, Hupp Motor Car Corp., spoke on "The Relation of the Metallurgical to Other Departments".

SPRINGFIELD CHAPTER

About 50 members visited the Rolls Royce plant on Dec. 3. This excursion proved to be a most interesting trip, and the courtesy of the company in opening its plant for inspection as well as the cordial reception of the visitors was thoroughly appreciated.

The Chapter held its meeting on Dec. 16 at the Chamber of Commerce. The speaker of the evening was V. E. Hillman, metallurgist, Crompton & Knowles Loom Works, his subject being "The Efficiency of Different Mixtures for Cyanide Hardening". Mr. Hillman's paper was illustrated with lantern slides.

TRI CITY CHAPTER

The Tri City Chapter had a very pleasant meeting on Friday, Dec. 9, when J. Fletcher Harper, research engineer, Allis-Chalmers Co., presented an interesting illustrated paper on the "Effects of Deep Etching". Mr. Harper's paper was thoroughly enjoyed by the large number present and an

interesting discussion followed. The National Secretary, W. H. Eisenman was also present and spoke to the members on "The Activities and Progress of the Society".

As an added attraction moving pictures of the Commonwealth Steel Co. were shown and produced a large amount of favorable comment. An excellent dinner at the Davenport Chamber of Commerce preceded the meeting. The local chapter is having a very successful winter; the meetings are well attended and have been uniformly successful. This success is due to a large measure to the co-operation the officers and executive committee received from the entire membership.

As a means of impressing upon members the dates of meetings, the Tri City Chapter sends to members desk blotters on the righthand end of which is a calendar for the month with the date of the meeting printed in red ink. The lefthand end of the blotter shows the date of meeting, place, speakers, subjects and chapter officers.

MILWAUKEE CHAPTER

The Milwaukee Chapter held its regular meeting at the Medford Hotel on Tuesday evening, Dec. 13. The National Secretary, W. H. Eisenman, paid a visit to the chapter and discussed with them the activities of the National Office during the past and the coming year. Moving pictures of the Commonwealth Steel Co. were shown, and proved very interesting to those in attendance.

CINCINNATI CHAPTER

The Cincinnati Chapter's November meeting was held on Nov. 25 in the Odd Fellows Temple. W. R. Fleming, of the Andrews Steel Co., presented an interesting paper on "The Influence of Nickel and Chromium in Steel" and was followed by a general discussion.

S. J. Felton, metallurgist, Lunkenheimer Co., presented a most interesting paper on "The Hardness of Steels and Cast Iron", on Friday, Dec. 16 at the Ohio Mechanics Institute.

PHILADELPHIA CHAPTER

The Philadelphia Chapter held its November meeting on Nov. 25, at 8:15 in the Engineers' club. The speaker of the evening was Arthur W. F. Green, John Illingworth Steel Co., his subject being "Preparing Tool Steel at the Mill."

WORCESTER CHAPTER

The Worcester Chapter has issued another of its mimeographed reports of discussions held at the meetings. This discussion was on Dr. Hoffman's paper and consisted of 12 pages. The sending of these mimeographed reports of discussions to members is meeting with pronounced favor.

The November meeting was addressed by W. C. Peterson metallurgical engineer of the Atlas Crucible Steel Co. Mr. Peterson covered the following points: Heat treatment of dies, reamers, broaches, dies, files, punches, saws, milling cutters, die blocks and chisels; various types of steel used;; hardening and drawing temperatures; breakage; causes of failure; importance of fillets; preheating; rate of heating; difference between water and oil hardening steels; steels for hot work; alloy steels; and machining strains. Because of Mr. Peterson's wide experience as supervisor of materials in the laboratory at the Packard Motor Car Co. for 12 years, he was able to speak from actual experience and an intimate knowledge of shop practice.

Commercial Items of Interest

AT A meeting, Nov. 28, members of the Founders' Association of Cleveland voted unanimously to disband the organization. The purpose of the action was not to discontinue work along co-operative lines, but to strengthen its activities through the Ohio State Foundrymen's Association and the founders' group of the American Plan Association of Cleveland. As many men are affiliated with these organizations, duplication of effort will be eliminated. The Founders' association was formed more than 20 years ago and has been reorganized several times. Thirty-two shops held memberships at the time of dissolution and 70 per cent of these were open shops.

"The Story of Mezzo," written by Col. E. C. Peck, general superintendent, Cleveland Twist Drill Co., Cleveland, has been published recently by that company. It is a 12-page booklet discussing the advance in the art of making tool steel and describing in particular a new grade of alloy tool steel used by the Cleveland Twist Drill Co. in the manufacture of drills. The booklet states "Heating the cutting edge of a drill to even a dark blue color will not draw its temper. In fact, it works at its best efficiency this way." On the last page of the booklet is a table showing the cutting specifications of various sized drills made from the new alloy steel.

A bulletin of the Bankers Trust Co., New York, department of foreign information, French section, says that statistics compiled by the *Economiste European* show the extraction of iron ore from mines in France during the first six months of 1921 amounted to 7,532,868 tons, showing an increase of 1,693,464 tons over the amount extracted during the same period last year. The total amount of cast iron produced in France during the first half of 1921 was 1,744,644 tons as compared with 1,272,518 tons during the first half of 1920, while production of steel for the first six months of 1921 was 1,527,950 tons as compared with 1,179,399 tons for the corresponding period of 1920. The bulletin concludes by saying "In spite of the evident progress over last year's production, the total output for the first half of 1921, still remains considerably inferior to France's producing capacity, which is estimated at about 700,000 tons for cast iron alone."

Research narrative No. 22 issued Dec. 1 by the Engineering Foundation, 29 West Thirty-ninth street, New York discusses American optical glass. This interesting little bulletin outlines briefly the supremacy of Germany in the manufacture of this glass before the war, and how the United States attacked the problem in 1914-15 with the result that trade secrets were overcome and a superior product was manufactured. In 1918 this country became an exporter and today maintains its position.

The Electric Furnace Construction Co., Philadelphia, announces that the Ford Motor Co., recently has ordered the largest electric melting furnace that has ever been designed or installed. It will have a capacity of 9000

kilovolt-amperes, which is three times the rating of any previously installed melting unit.

Rebuilding of the plant of the Ellwood Ivin's Tube Works, Philadelphia, which was completely destroyed by fire a year ago, is now going on and some of the buildings have been completed. One of the mills now is op-

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelop containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

FOREMAN OR ASSISTANT FOREMAN. Two years as hardener and two years as foreman of heat treating department, where employed at the present time. Has also had course in Metallography. Eastern location preferred. 1—11

CHEMIST & METALLURGIST. Ten years genera experience in chemistry covering coal, oils, paints and varnishes, rubber, brasses, steels and cement. Five years experience in analysis, manufacture and heat treatment of tool and alloy steels. Was foreman in charge of electric furnace for 2 years. Location around Chicago preferred. Married. Salary desired $150.00. 1—12

HEAT TREATING FOREMAN. A man with six years experience in the hardening of tools, dies, etc., desires a position where he can use his knowledge to the best degree. Has worked in some of the largest plants in the country and can furnish the best of references. Address 1-5.

METALLURGICAL ENGINEER. Extensive experience with large firms and steel mills. Has served as metallurgist in large production steel mill, Age 27, Married. No preferences as to location. Willing to consider any position in the metallurgical department, annealing or heat treating departments providing there is an opportunity for advancement. Address 1-10.

METALLURGIST—With twelve years experience with automobile, locomotive, munitions and alloy steel manufacturers. Familiar with the manufacture, heat treatment and properties of all general iron and steel specifications, Open Hearth, Electric Furnace and Cupola practice. Age 30, married. Address 1-15.

SUPERINTENDENT OR FOREMAN—In heat treating department; 21 years experience in heat treating. Employed at present with large heat treating plant. Desire to make change. Salary desired $3000. Address 10-2.

TECHNICAL GRADUATE—As metallurgist or superintendent of heat treating department. Six years of extensive experience in chemical and physical testing and heat treatment of carbon and alloy steels in automobile and aeronautical motor plants. Best of references. Eastern location preferred. Salary desired $250 per month. Address 11-1.

METALLURGICAL ENGINEER—Columbia University graduate. 7 years experience in steel treating plant, also research department of large steel manufacturing company. Experience included laying out and overseeing commercial heat treatments of small automobile parts, and similar products, and testing of same; design and installation of heat treating equipment; installation and maintenance of pyrometers; research work on high tensile and shock resisting structural steels, tool steels, magnet steels, etc.; micro examinations and microphotography; magnetic measurements; critical temperature measurements. Salary $200—$250 per month, depending on location Address 10—3.

HEAT TREATING FOREMAN—Two years pyrometrical and heat treatment of gun forgings; one year heat treatment and physical testing of rolled bar stock, and simple analysis; 1½ years heat treatment, carburizing, and hardening of automobile forgings. Address 9-5.

FOREMAN: 30 years practical experience in heat treating, forging tool hardening, carbonizing. 5 years as foreman of heat treating. Location preferred in Pennsylvania, New Jersey, or Maryland. Salary desired $200 per month. Address 9-3.

CHEMIST OR HEAT TREATER—Technical graduate. Experience in chemical and physical testing, heat treating of steels, platinum metals and rare earths. Best of references. Reasonable sa lary. Address 12-10.

POSITIONS OPEN

The following positions are open in the heat treating department of the United States Naval Ordnance Plant:

SUBFOREMAN—Heat treatment of large guns and forgings, at $7.36 per day.

SUBFOREMAN—heat treatment of projectiles, at $7.36 per day.

SUBFOREMAN—Heat treatment of small guns, at $7.36 per day.

Application blanks may be secured from the labor board of the Ordnance Plant, South Charleston, West Virginia, or from the secretary of the Fourth Civil Service District, Washington D. C

erating and others will be started as soon as completed. Electric power will be utilized entirely. The plant was established 27 years ago. Accurate cold-drawn seamless steel tubes of high finish are specialized in by the company.

R. L. Warburton, connected with the Celite Products Co., New York, for a number of years, has become identified with the Quigley Furnace Specialties Co., 26 Cortland street, New York, as a sales engineer.

The Carroll Chain Co., Columbus, O., was incorporated Nov. 1, 1921, to manufacture a complete line of welded chain. Ground has been broken for the erection of a modern plant. New equipment will be installed as building progress permits. The company will produce both fire-weld and electric-weld chain, but will begin operations by confining the manufacture to the fire-weld varieties, giving special attention to steam shovel and dredge chains.

"Forge Note Book" is the title of new book arranged by George T. Coleman, Lane Technical High School, Chicago and published by the Bruce Publishing Co., Milwaukee. By way of review *The Iron Trade Review* says:

"This book is designed for the use of students in technical schools where the fundamentals of forge practice are taught. The essential equipment, including the forge, fire tools, hammers, tongs, punches, cutters, dies, mandrels, vises, surface plates, etc. are described and illustrated. The materials used in forge practice including

(*Continued on Page 36*)

This qualification record will be printed in the "Men available" section of the Employment Bureau of the Transactions at a cost of 50c each insertion.

The money to cover this Charge should accompany this form.

QUALIFICATION RECORD—Strictly Confidential

Name

Address

No. of Years in Grammar School?	**Other Schools?**

Experience:

Wages Desired?	**Location Preferred**	**Kind of Position Desired**

(*Continued from Page* 35)

the various kinds of wrought iron and steel, etc., together with the fuel, are described and methods for calculating the required amount of stock are given. Simple forge operations, including drawing, upsetting, twisting, offsetting, bending, welding, chainmaking, etc., are described in detail. Several paragraphs also are devoted to the subjects of annealing, case-hardening, forging of tool steel, tempering, and handling of high speed steel."

Bell & Gosset, Chicago representatives of the Quigley Furnace Specialties Co., 26 Cortlandt street, New York, have been succeeded in that capacity by H. M. Thompson, formerly with the Thomas Moulding Brick Co., Chicago.

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